A PRACTICAL COURSE IN CONCRETE

PORTLAND CEMENT ASSOCIATION

A PRACTICAL COURSE IN CONCRETE

A TEXTBOOK FOR

CLASSROOM AND LABORATORY

INCLUDING

DEMONSTRATIONS AND PROBLEMS

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The monolithic concrete Los Angeles County General Hospital, Los Angeles, Calif., built in 1930. Enough concrete was used in this structure to build forty-two miles of eighteen-foot concrete road.

CHAPTER I

Foreword

PURPOSE

CONCRETE as a construction material is eminently suited for many uses. It is permanent, sanitary, and fire resistant. The upkeep cost of concrete is low, and it can easily be made attractive in appearance. Being plastic when first mixed, concrete lends itself well to the construction of many objects.

On the other hand, perhaps no other material depends so much for its success upon the user. Good materials, accurate proportioning and careful control in all operations are essential to the making of good concrete.

This fact makes desirable the organization of practical courses in concrete in our schools.

Many splendid publications relating to concrete are now available to the user. A complete treatise of the subject would require much more space than is available here. However, it is the intention in this manuscript to provide a teaching background which can readily be supplemented with more detailed material from other sources.

Mere statement of fact often fails to carry its point, whereas demonstrations or practical applications are effective. A number of demonstrations, resulting from presentation to classes of prospective teachers, have been included to illustrate and emphasize points which are important but frequently not observed in actual practice.

Practical concrete work should be allowed sufficient time for adequent presentation. It should be carried on with a purpose and should lead to an understanding of the properties of concrete, the selection of materials, and their proper manipulation as well as the doing of some actual projects. The exact balance between demonstrations and field practice will depend largely upon the situation at hand and the amount of time available.

COURSE OBJECTIVES

In preparing his course outline, the teacher should be thinking rather carefully of what he expects to

Concrete serves in many ways to make travel safe and easy. This bridge spans the Rouge River in Oregon.

accomplish. The following objectives are suggested:

1. To develop an appreciation of the utility and possibilities of concrete and masonry construction.
2. To secure an understanding of the properties of cement and concrete and the importance of good materials and proper manipulation in obtaining a satisfactory product.
3. To develop skill in handling cement and concrete.

A course in concrete offers some advantages to the teacher in presentation because of the varied means at his disposal for accomplishing the solution of related problems. In general they are:

1. Class recitations and demonstrations.
2. Assigned outside reading and home projects.
3. Laboratory exercises.
4. Field experience and observation.
5. Written work.

Too much emphasis can scarcely be placed upon the planning of a systematic procedure. After one has the subject matter well in hand, he should plan his attack so that his ideas will carry over to his students in a most effective way. Require complete and well arranged notes. Since it is difficult to forecast the time and equipment which will be available for the public school course, design a flexible one. This involves not only a careful arrangement but also the rating of problems so that the most important can be covered in a short course and others added if time permits.

TEXTS AND EQUIPMENT

A bibliography of supplementary publications is given on page 62 of this manual. Copies of many of these should be in the school library.

Each student should have the following equipment:

1. A good loose leaf notebook (8½ x 11).
2. Work clothes.
3. About one gallon of bank run gravel (preferably from the source used at home) to be used in the various tests of aggregates.

REPORTS

Accurate and carefully prepared reports should be required of all demonstrations and tests covered in the course. These should be arranged and divided so that the organization is apparent.

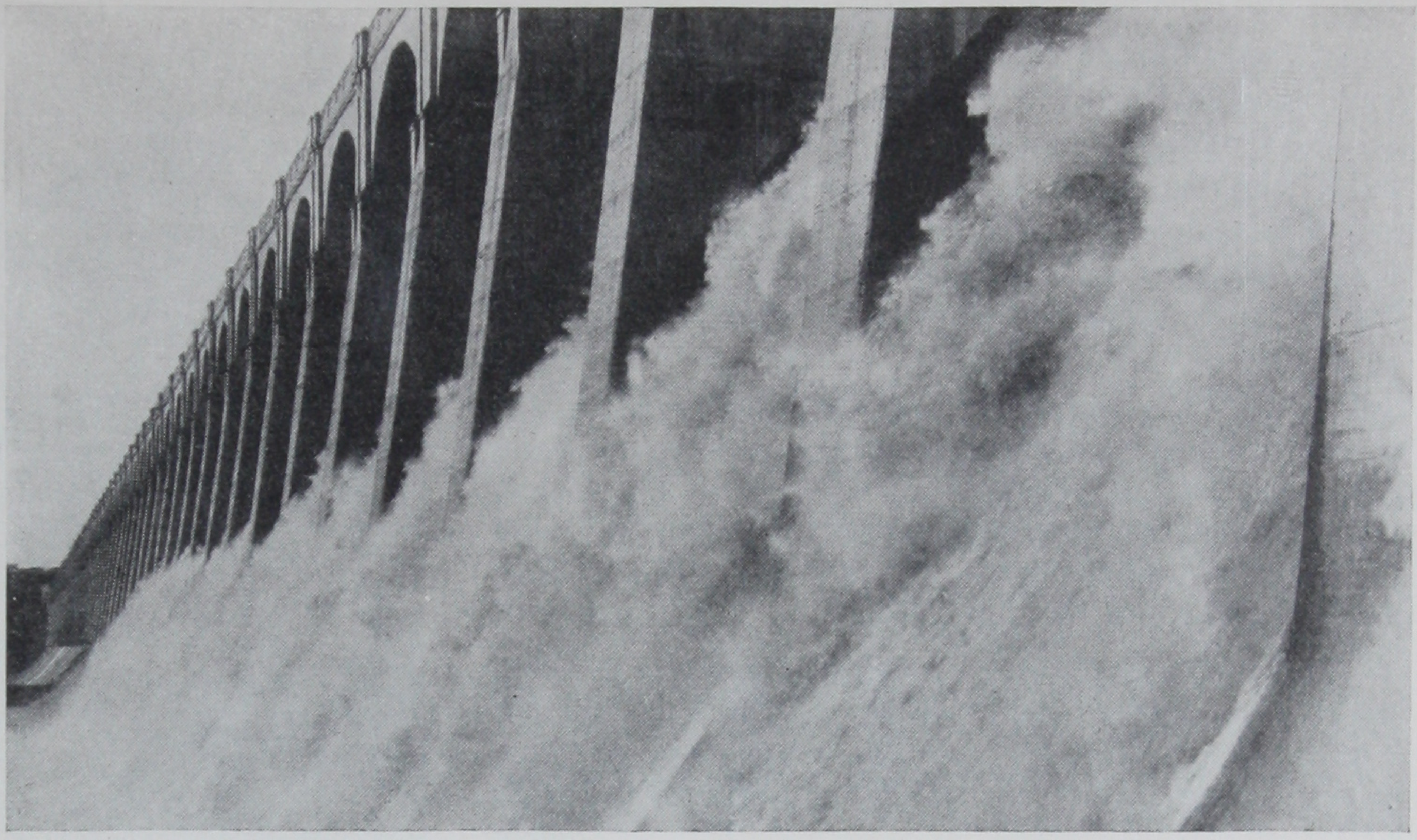
The following headings have been quite satisfactory:

1. Purpose.
2. Equipment used.
3. Method.
4. Results.
5. Conclusions.
6. References.

A fireproof apartment house built of monolithic concrete. All decoration on the outside walls was cast in place as the walls were built, using molds built into the forms.

Interior of the Shrine of the Sacred Heart, Washington, D. C. Rich color effects were achieved in concrete here by use of exposed colored aggregates.

Flood waters of the Tennessee River, held back by Wilson Dam, Muscle Shoals, Ala., generate electric power for a vast area in southeastern United States. Nearly a mile from end to end, this dam is the longest in the world.



If this plan is followed, the report will show at a glance the essential facts.

The following list of demonstrations is suggested. Detailed descriptions are given on the pages indicated.

A—Selection of Materials.

1. Fineness of cement (page 13).
2. Silt test of aggregates (page 13).
3. Colorimetric test for organic materials (page 14).

B—Theory of Proportioning.

4. Water-cement ratio: demonstration of principle (page 16).
5. Water-cement ratio: beam tests (page 16).
6. Measuring moisture in sand (page 19).
7. Effect of size of sand particles upon the percentage of voids (page 21).
8. Effect of size of sand particles upon surface area (page 22).
9. Percentage of coarse and fine aggregate in bank run material (page 23).
10. Gradation of fine aggregate (page 23).
11. Bulking of sands (page 25).

LABORATORY INSTRUCTIONS

These general instructions should be carefully followed throughout the laboratory course:

Use any equipment that you may need to carry on your work but when you are through with it, return it to its proper place so someone else will use it. The usefulness of testing sieves, scales, etc., depends upon their accuracy. Use them with care.

All apparatus must be returned clean and in good condition. In order to facilitate cleaning of metal forms a thin application of oil is applied with a brush before the concrete is put in place. When making small test pieces an oily cloth is preferable for oiling the inside of the molds and the surface of the glass.

After removing forms they must be cleaned with a stiff wire brush and re-oiled before putting them away. This is essential in order to avoid corrosion.

To avoid confusion, all test pieces must be carefully numbered, dated and preferably marked with the owner's initials.

All reports should be carefully prepared. At the end of each period a fairly complete report should be made of the work done, but certain things must be recorded as the work is carried on. When you weigh or measure materials do not trust to memory but record immediately.

PROCEDURE IN THE COURSE

In offering any course, there are problems in choosing the order of presentation. Individual cases may justify the rearrangement of a well-planned course. Seasons and variable weather make it necessary in a course in concrete to take advantage of good days for field work. In general, the order of presentation as given in this manuscript is suggested.

Laboratory work should be very closely correlated with class work. A discussion of the quality of aggregates and the necessity for making certain simple tests should be followed up by making the tests in the laboratory. Likewise, the theory of proportioning might well be accompanied by making test beams and proportioning of concrete in the field. Everything of a theoretical nature should find application in a project of interest to the student.

CHAPTER II

Materials

PORTLAND CEMENT

SINCE, in concrete construction, it is common to buy the materials or ingredients rather than the finished product and since some of these may vary greatly in quality, a course in concrete should begin with a discussion of what concrete is and what materials are necessary in order to make good concrete.

Concrete is a mixture in which a paste of portland cement and water binds fine and coarse materials, known as aggregates, into a rock-like mass as the paste hardens through the chemical action of the cement and water. It is, then, composed of an active material (cement) and inert materials (aggregates). It might also be termed a mass of inert materials held in place by a binder.

The quality of concrete depends upon the quality of materials, proportioning and workmanship. The economy depends upon the manner in which these are combined to secure a dense, compact mass with a minimum of binder. The binder constitutes the more expensive ingredient. The inert materials are relatively inexpensive. A good concrete has all surfaces of the aggregate thoroughly coated with the paste and all voids filled.

Mortar is a mixture similar to concrete in which no large size aggregate is used.

The Castle of St. Angelo, in Rome, built in 138 A. D. as a tomb for Emperor Hadrian. Its massive foundation and walls were constructed of pozzuolana concrete, made with a natural cement.

The great dome of the Pantheon in Rome, built of concrete 1800 years ago, as it appears today.

History of Cementing Materials

Cements and limes have been used since the dawn of civilization. The famous Appian Way, the great system of aqueducts, and other structures built by the Romans, are today in an excellent state of preservation.

Notwithstanding the early use of these materials, little was known of their chemistry, and no substantial advance was made in the manufacture of lime and cement from the time of the Romans until 1756. In that year, John Smeaton, who had been employed by the English government to build a lighthouse in the English Channel, discovered that an impure or clayey limestone, when burned and slaked, would harden into a solid mass under water, as well as in air. This discovery of Smeaton's paved the way for rapid improvement and development in the lime and cement industries.

In 1796 James Parker, of Northfleet, England, ob-

Horace Greeley residence, Chappaqua, N. Y., built in 1857. This is the oldest concrete house in America.

tained a patent for the manufacture of a cement which he aptly named Roman cement. Parker's process consisted of burning certain stone or clayey products called "nodules of clay" in an ordinary lime kiln, and then grinding to a powder. Cement produced in this manner rapidly gained favor among engineers and builders, and resulted in natural cement plants springing up all over the continent of Europe, in England, and later, about 1818, in the United States. In 1824 Joseph Aspdin took out a patent in England for the manufacture of an improved cement, produced by calcining a mixture of limestone and clay. To the resulting powder he gave the name of *portland cement,* because, when it hardened, a yellowish-gray mass was produced, resembling in appearance the stone found in various quarries on the isle of Portland, England. To Joseph Aspdin is given the credit of making the first portland cement, and he is generally recognized as the father of the modern portland cement industry.

Aspdin's product, however, probably differed considerably from the portland cement of today. Available records indicate that his cement was burned at lower temperature, and that it was pulverized by slaking with water rather than by grinding. It is probable that Isaac Johnson, of Swanscombe, Kent, England about 1845, was first to discover the merits of burning at such high temperatures that the product would not slake but had to be pulverized by grinding. This is one of the essentials of portland cement as we know it today.

In this country the cement industry began with the discovery, in 1818, of a natural cement rock near Chittenango, N. Y., by Canvass White, an engineer on the Erie Canal. In 1825, cement rock was found in Ulster County, N. Y., and in 1828 a mill was built in Rosendale, New York.

In the spring of 1866, D. O. Saylor, Esaias Rehrig, and Adam Woolever, all of Allentown, Pa., formed the Coplay Cement Co. and located a mill near Allentown for the manufacture of natural cement. Mr. Saylor began early in the seventies to experiment on portland cement from the rock in the quarries. After many experiments and trials, true portland cement was produced in 1875. This was the first portland cement made in the Lehigh district and probably in the United States.

This, then, was the small beginning of the American portland cement industry, which has grown from a production of about 83,000 barrels in 1880, and less than 1,000,000 in 1895, to the total of approximately 176,000,000 in 1928. (One barrel equals four sacks.)

The present portland cement is a finely pulverized material consisting principally of certain definite compounds of lime with silica, alumina and iron oxide, which is capable of hardening into a solid mass through chemical combinations of the various compounds with water.

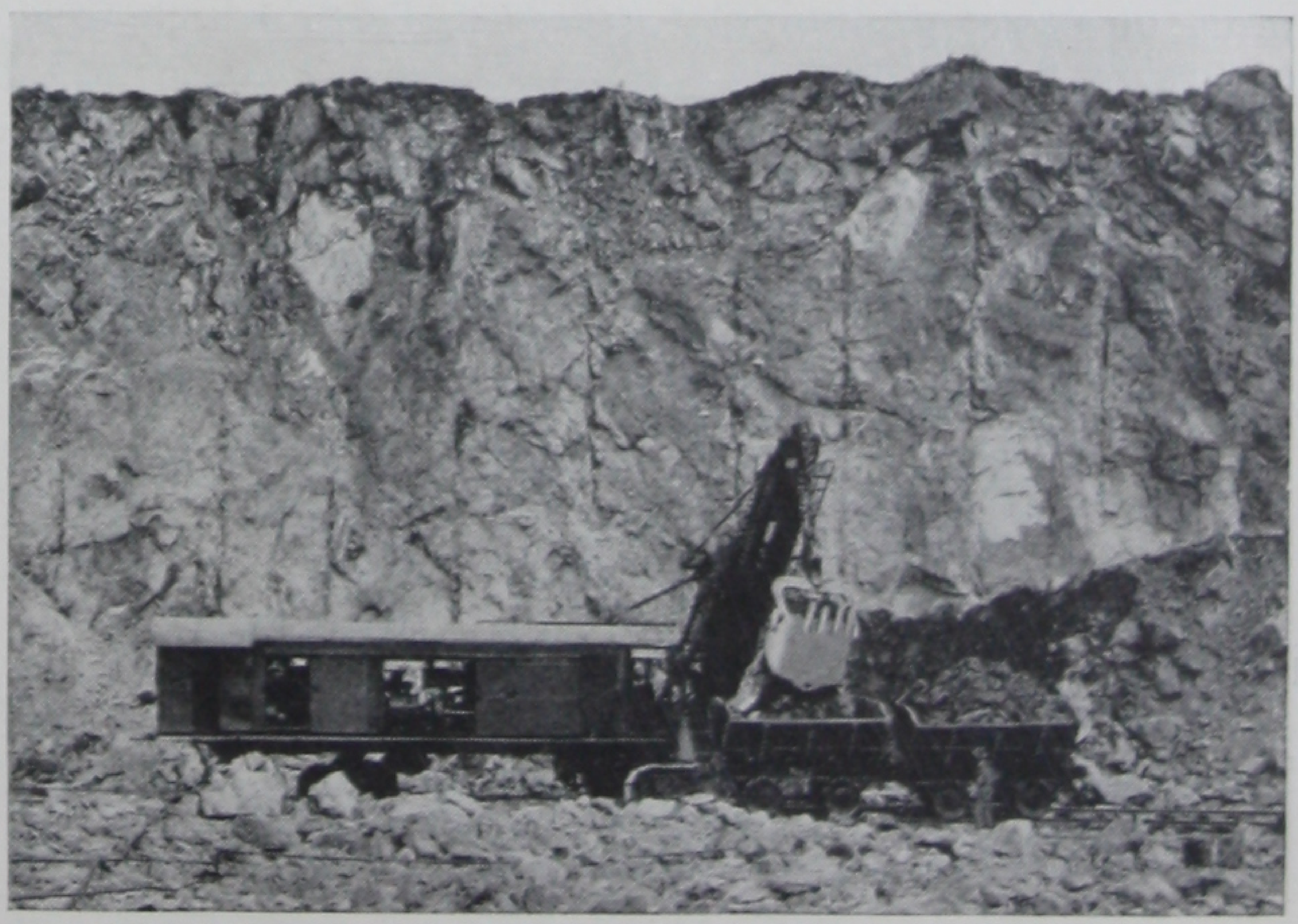
The Manufacture of Portland Cement

Nature has provided an abundance of calcareous and argillaceous materials suitable for the manufacture of portland cement. The calcareous variety is always in the form of calcium carbonate such as limestone, chalk, marl, oyster shells, or the precipitated form obtained as a waste-product from the manufacture of alkalis. The argillaceous division includes clay, shale and slate, cement rock, and selected blast furnace slag. Cement is made in this country from all these materials, each plant using one of the calcareous combined with one of the argillaceous materials.

Portland cement may also be divided into classes, according to the method of manufacture:

1. Wet process.
2. Dry process.

In the wet process, the raw materials are intimately mixed, ground, and fed in the form of a "slurry" (con-



Quarrying limestone, one of the principal ingredients of portland cement.

taining sufficient water to make it of a fluid consistency) into the rotary kilns. In the dry process, raw materials are ground, mixed, and fed to the kiln in a dry state.

The various operations in the manufacture of portland cement by the dry process are:

1. Mining and quarrying of raw materials.
2. Crushing.
3. Drying.
4. Grinding.
5. Proportioning and mixing.
6. Pulverizing.
7. Burning the mixed materials to incipient fusion.
8. Grinding the clinker thus burned to an extremely fine powder, meanwhile adding the proper proportion of gypsum, the resulting powder being known as portland cement.

In the wet process, instead of drying raw materials, water is added. In some plants, part of this water is removed by filtration prior to burning. Some plants combine grinding and pulverizing into a single operation. Otherwise, the wet and dry processes are essentially alike.

The excavation of the raw materials is the first step toward the actual manufacture of portland cement. The natural raw materials are worked by one of three general methods: First, quarrying and digging from open pits. Second, mining from underground workings. Third, dredging from deposits covered by water.

The method of quarrying the rocks usually follows custom. The rock is dislodged from the quarry face by means of an explosive and then loaded into side dump cars or aerial trams by either steam shovel or manual labor, preferably the former. The stone is then conveyed to the stone house, where it is crushed to comparatively small sizes, dried, and then transported to storage-bins before being mixed with the other ingredients. While in storage, the stone may be sampled and analyzed. Another method used is to pass the limestone, shale, or cement rock through crushers and ball mills, or other preliminary grinders, from which it is

A portland cement mill. More than 160 such plants, in every part of the United States, supply the cement needed for modern construction.

conveyed to storage-bins. The ball mills are revolving cylindrical steel drums containing a quantity of steel balls. The material to be ground, after drying, is continuously added. As the cylinder rotates, the balls roll, thus grinding the rocks to coarse grits. The coarse grits are then run into storage-bins.

Shale, which for practical purposes may be looked upon as solidified clay, is excavated, dried, ground, and then conveyed to storage-bins.

After the raw materials have been drawn from their respective bins and accurately proportioned by weighing, they are delivered to a screw conveyor which delivers the combined material to the tube mills. The tube mills are similar to ball mills but of greater length. These reduce the material to practically the fineness of finished cement.

All the tube mills deliver to the same conveyor, which results in a uniform product of the raw material mill as a whole. At frequent intervals, samples are taken from the conveyor and delivered to the laboratory for tests of composition.

From the tube mills the material is fed to the kilns through a system of conveyors. The kilns themselves are revolving cylinders from 6 to 11 ft. in diameter and from 100 to 440 ft. long. They are lined with refractory brick and revolve at the rate of about one revolution per minute. It is estimated that a particle of raw material takes about one hour to traverse the entire distance from the feed to the outlet. Powdered bituminous coal, crude oil, or gas is used as fuel. It is blown into the kiln at the end opposite that at which the raw materials enter.

The raw material entering as a powder is gradually brought to the point of incipient fusion at a temperature of 2500° to 3000° Fahrenheit, producing clinkers varying in size from ¼ inch up to about 1½ inches in diameter. Through smoked glasses, experienced workmen are able at all times to note the condition within the kiln. The clinker, red hot when discharged, is soon cooled by sprays of water or cold-air blasts either in specially designed coolers or after the clinker is delivered to the storage piles.

From the kiln, the clinker may go—(a) to the clinker storage pile for later grinding, or (b) directly to the grinding department.

Either before or after the preliminary grinding of the clinker, it is usual to add approximately two pounds of gypsum to every 100 pounds of clinker, to retard the setting time of the cement. This is controlled by the chemist from analyses of the finished cement and from "the time of setting" determinations made hourly in the physical laboratory.

After the gypsum has been added, the material is delivered to the tube mills, which complete the grinding. Standard specifications require that at least 78 per cent of the cement pass through a sieve having 40,000 square openings per square inch, called a 200-mesh sieve. The average cement of today exceeds this require-

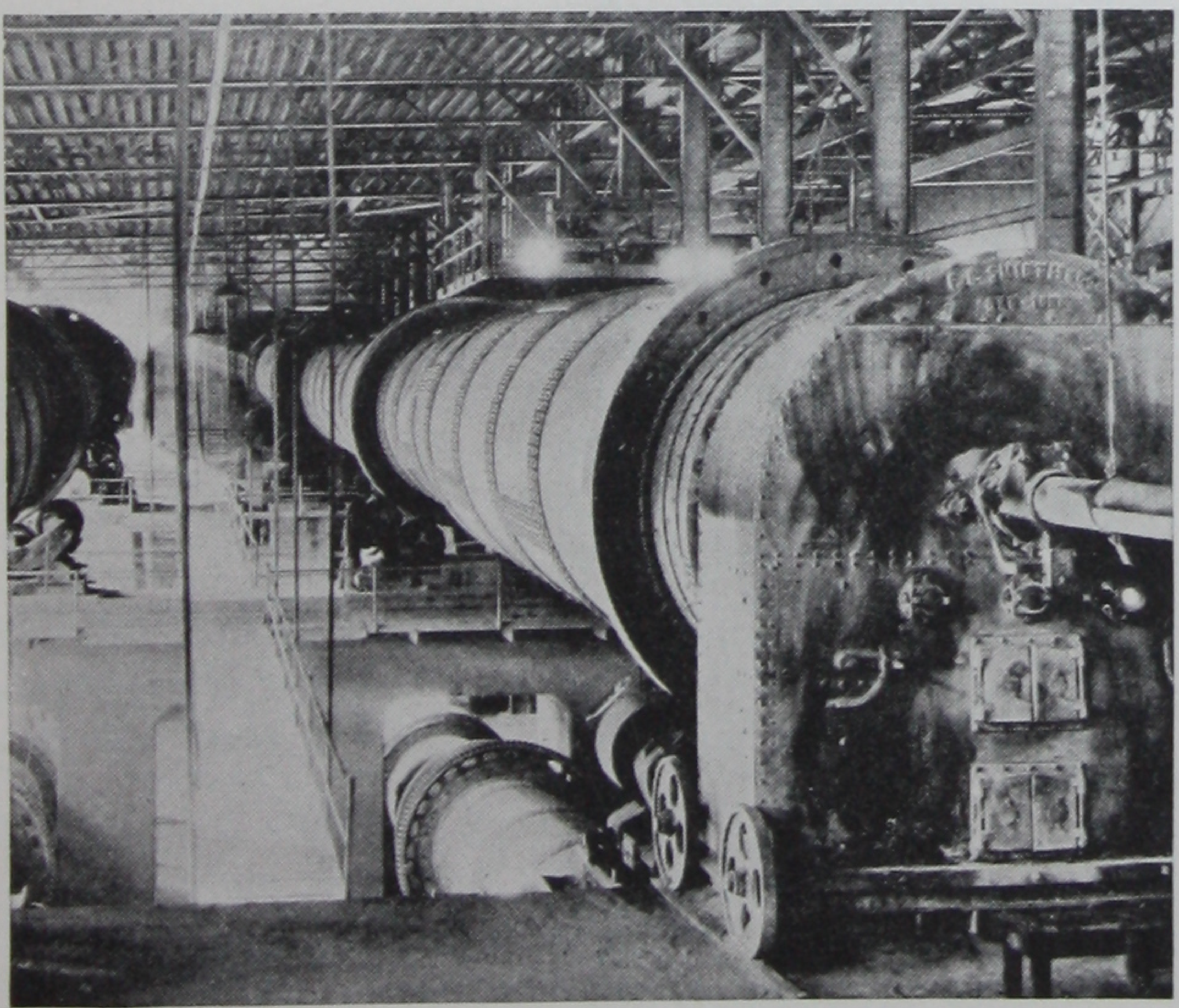
ment by a considerable margin. Frequent samples are taken and tests made of the finished product.

The material is deposited in storage bins, similar to those used in storing grain, by means of a conveyor belt. From the bottom of each bin, conveyors carry the cement to large elevators, which raise it finally to large hoppers above the packing floor. A cement sack is first tied and then filled by machine through a valve or flap in the bottom. The valve may be discovered by careful inspection of any of the standard sacks used today. The filled sacks are placed on a conveyor belt which unloads them within a few feet of the car, ready for shipment.

Setting and Hardening of Portland Cement

When portland cement is mixed with enough water to form a paste, the compounds of the cement react with the water to form both crystalline and jelly-like products. These products adhere to the aggregate and to each other and become very hard. If the concrete is kept moist, the reactions may continue for years, and thus the product becomes progressively stronger over a long period of time.

The water-cement paste remains plastic for a short time but as the reactions with the water proceed, the mix begins to stiffen or "set." At this stage of the "setting," it is still possible to disturb the material and remix without injury, but as the reactions between the cement and water continue, the mass completely loses its plasticity, and if disturbed or remixed, the strength will be seriously impaired. This early period in the hardening of cement is spoken of as the "setting period," although there is no well-defined break in the hardening process. Once the mass has definitely hardened, the chemical action continues, building up a firm internal structure which increases in hardness and strength as the action proceeds. The "set" and subsequent hardening process are the same whether the cement is used alone or in combination with aggregates.



In huge revolving kilns, cement is burned at temperatures exceeding 2700° F.

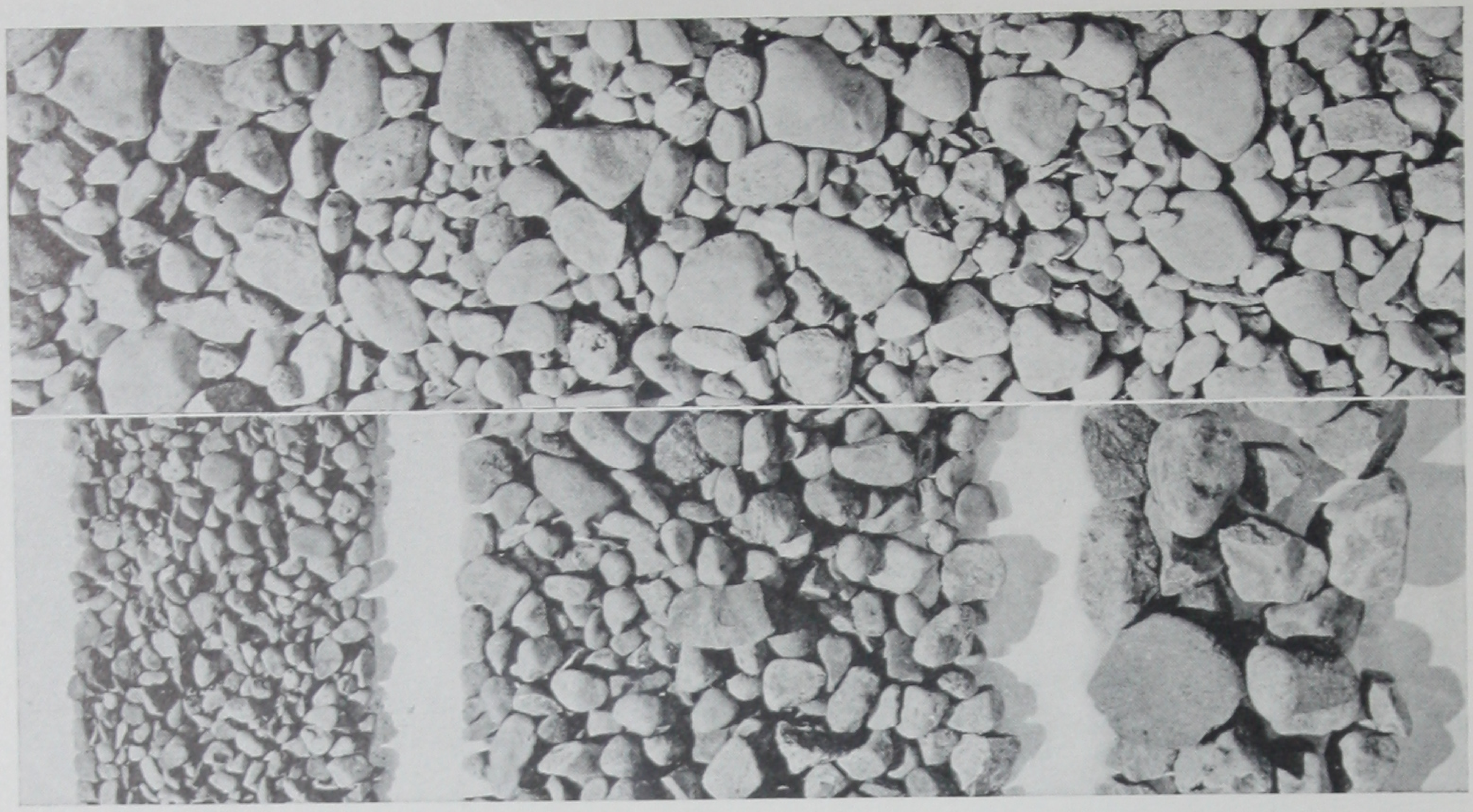
The impression of an ash leaf on a concrete pavement, photographed after 18 years of exposure to traffic and weather—remarkable evidence of the durability of concrete.

Special Portland Cements

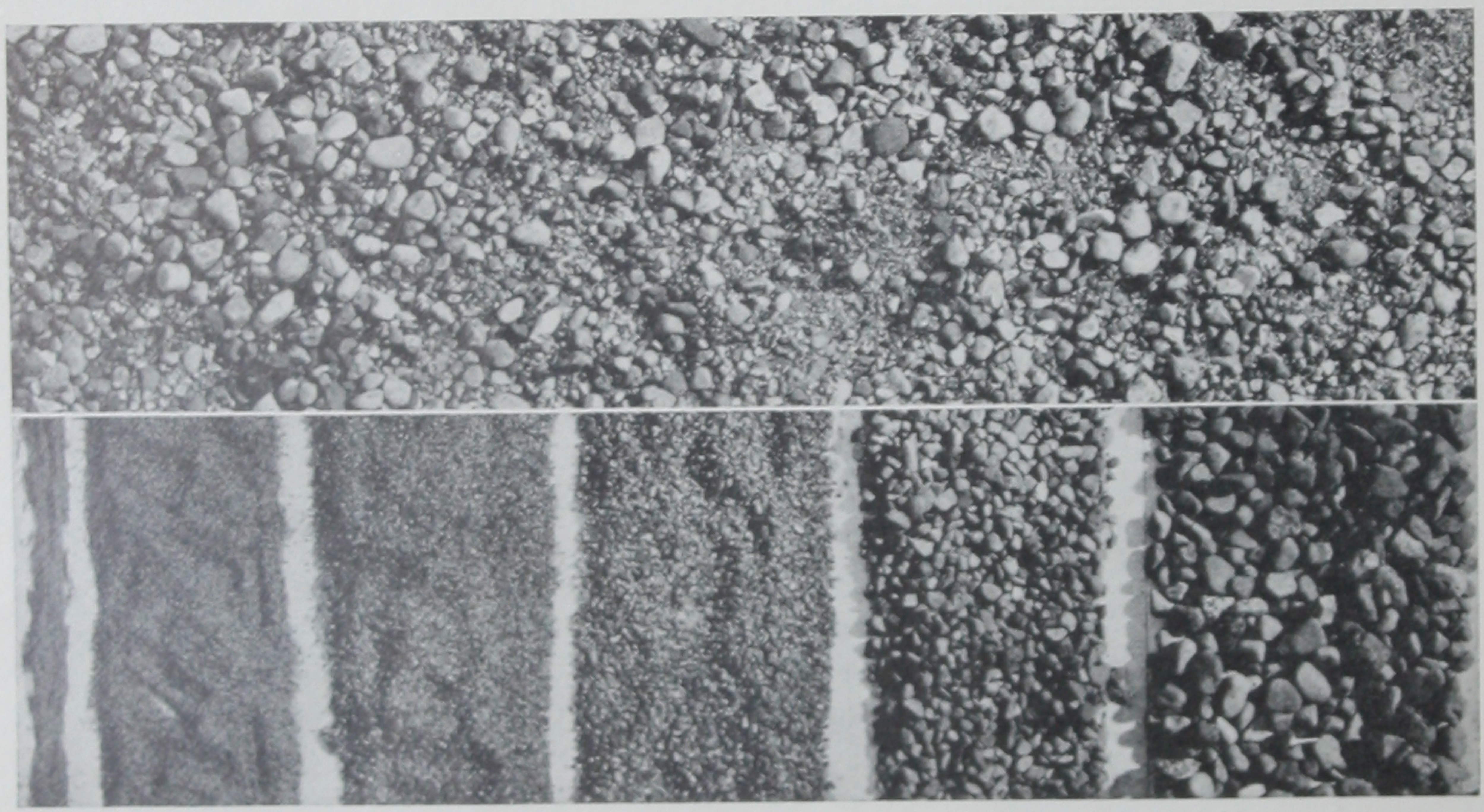
In addition to the standard or normal portland cement, special portland cements have been developed for specific uses. Cement as ordinarily marketed is grayish in color and is often termed gray cement. One can obtain at a somewhat higher price, *white* cements which are made from carefully selected raw materials. These conform in all respects to the chemical specifications for normal cement and are used where whiteness is an added advantage. Other cements are now available under the general classification of *high early strength* portland cement. These harden much more quickly than normal portland cements and are used where high early strength concrete is desired.

The manufacture of portland cement is so carefully controlled that for ordinary uses it does not seem advisable to recommend tests which are complicated and difficult to make. Often, however, one can profitably introduce a demonstration which will tend to draw attention to interesting facts. Two of these are suggested in connection with cement. Fineness of grinding is of interest not only because material is crushed to almost incredible fineness, but also because the coarse particles appear almost entirely chemically inactive.

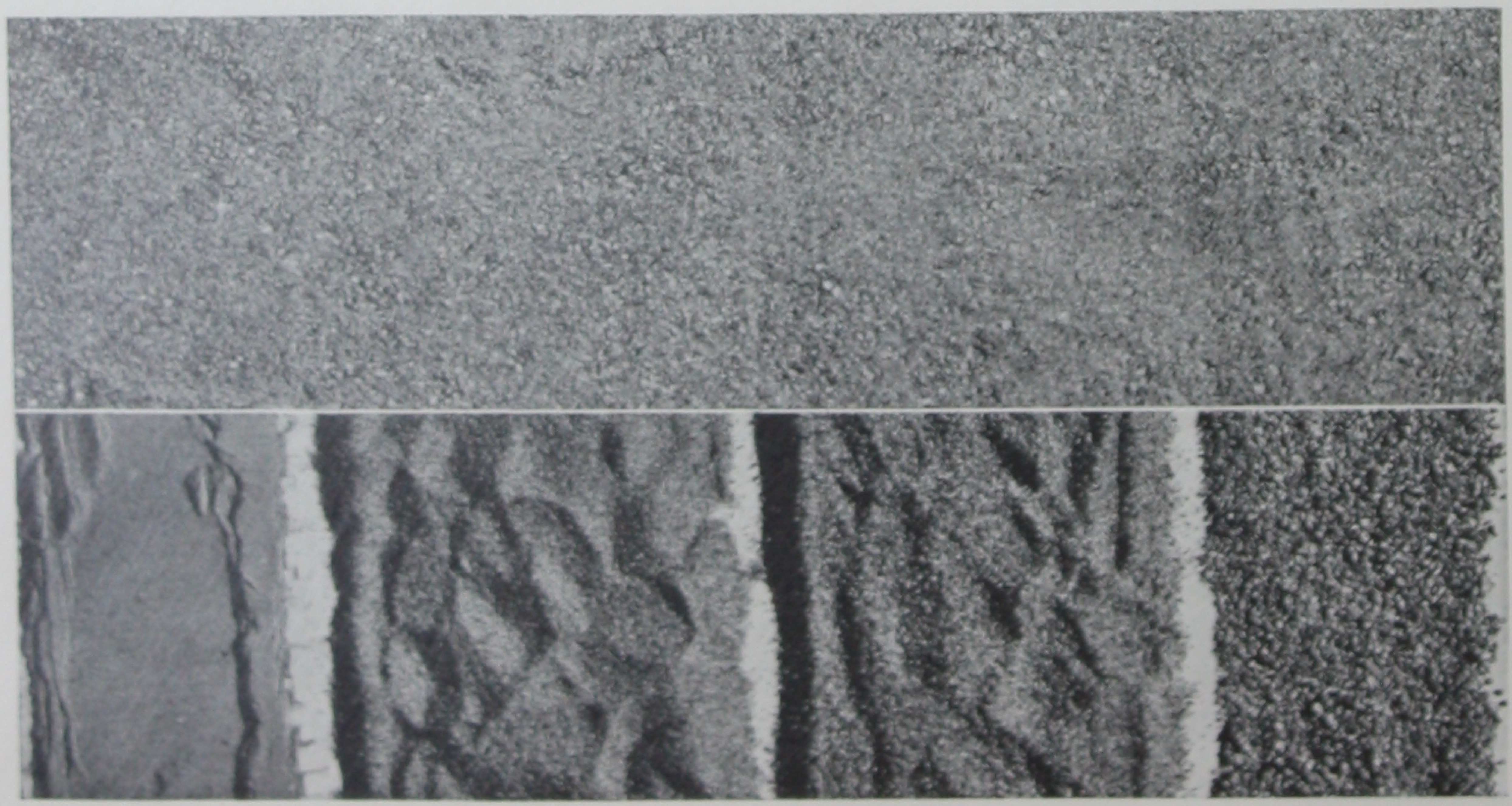
The cement clinker, before grinding, is stored in the open and apparently is not affected by water. After grinding, however, cement is easily damaged by water, and will even absorb moisture from the atmosphere in time unless properly protected. Cement should, therefore, be kept in a dry place at all times prior to use. Cement which contains lumps that cannot be pulverized by striking lightly with a shovel, should not be used. Cement that is caked due to weight of cement piled on it can be reconditioned by rolling the sack on the floor.



This is how a well-graded coarse aggregate looks before and after being separated into three sizes. From left to right in the separated aggregate: $\frac{1}{4}$ to $\frac{3}{8}$-in., $\frac{3}{8}$ to $\frac{3}{4}$-in., $\frac{3}{4}$ to $1\frac{1}{2}$-in. Note how the smaller pieces fit in among the larger ones in the mixed aggregate.



Sample of well-graded sand before and after separating into various sizes. Particles vary from fine to those just passing the No. 4 sieve. Width of strip indicates amount of each size.



Sample of sand which lacks particles larger than $\frac{1}{16}$ inch in size. More cement is required when sand is fine. This is not a good concrete sand.

Fineness of Cement (Demonstration No. 1)

The almost incredible fineness to which cement is ground and also the way fineness of grinding affects the early hardening may be demonstrated easily with the following equipment:

1. Cement.
2. Water.
3. Standard testing sieves: 100 and 200-mesh.
4. Molds for cement pats.

Screen the cement in turn through the 100-mesh and 200-mesh sieves, saving the material retained on each. Note how little cement is retained and how much original material must be screened to secure a sample large enough to make a small pat.

Make a paste of water and (1) cement retained on the 100-mesh sieve, (2) cement passing the 100 but retained on the 200-mesh sieve, (3) cement passing the 200-mesh sieve. Place in small molds so that each may be later observed under identical conditions. After 48 hours, note the difference in character of the three specimens. The coarser particles are almost entirely lacking in cementing power.

MIXING WATER

In general, water that is fit to drink is suitable for mixing with cement. Water should be clean and free from oil, alkali or acid.

AGGREGATES

Fine aggregate includes all particles from very fine (exclusive of dust) up to those which will just pass through a screen having four meshes to the linear inch. Coarse aggregate includes pebbles, crushed stone or crushed slag cinders, burned shale and other suitable materials ranging from ¼ in. up to 1½ in. or more in size. The purpose of this division is to insure uniform proportions in different batches of concrete and to avoid segregation in handling.

The largest size of coarse aggregate to use is governed by the nature of the work. For example, aggregate 1½ in. or more in size may be used in a thick foundation wall or heavy footing. In thin slabs or walls, it is recommended that the largest pieces of aggregate should never exceed one-third the thickness of the concrete being placed. The maximum size should never be larger than three-quarters of the width of the narrowest opening through which the concrete will be required to flow in the forms during placing.

Aggregates which are sound, hard and durable are best suited for use in concrete. Aggregates which are soft, flaky and which will wear away rapidly through exposure to weather, generally are unsatisfactory.

In addition to being sound, hard and durable, the best aggregates are clean and free from loam, clay or vegetable matter. These materials are objectionable because they prevent the cement paste from binding together the particles of sound, durable aggregates, thereby reducing the strength of the concrete and making it more porous. Concrete made with dirty aggregates hardens slowly and may never harden enough to serve its intended purpose.

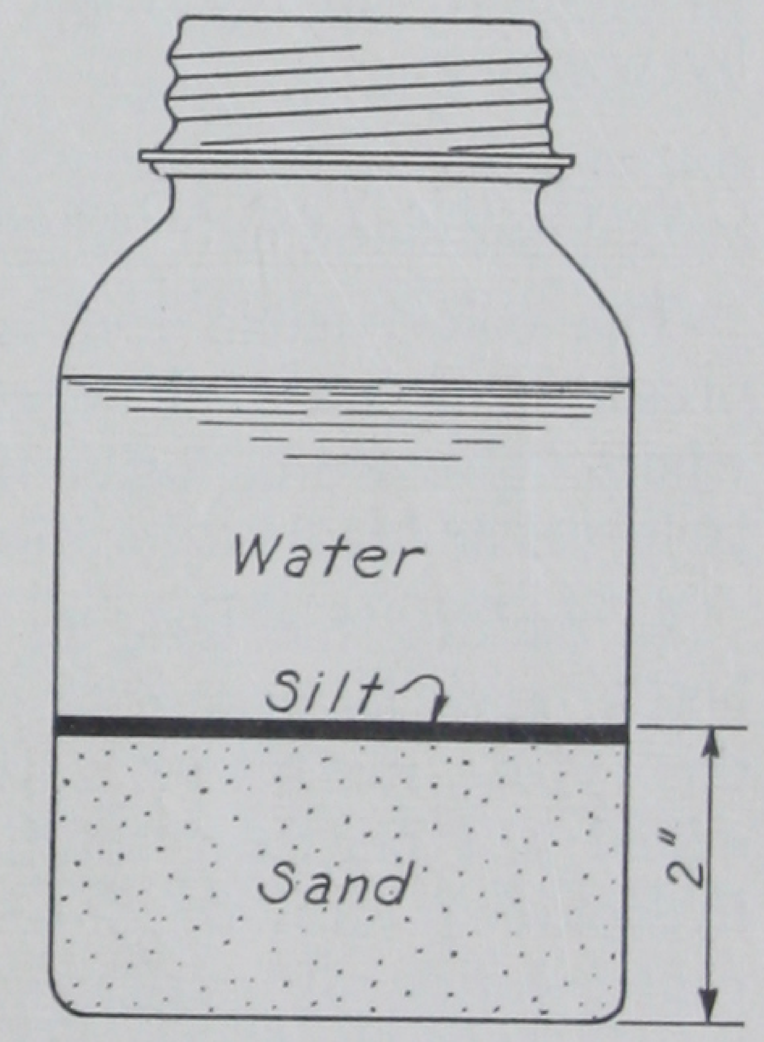
Methods for making tests to determine whether or not aggregates contain harmful amounts of dirt or vegetable matter are outlined below.

Well-graded fine aggregate, in which the particles are not all fine or all coarse but vary from fine up to those particles which will just pass a screen having meshes ¼ in. square, is recommended. If the sand is well graded, the finer particles help to fill the spaces (voids) between the larger particles, thus resulting in the most economical use of cement paste in filling the voids and binding the aggregate together to form strong concrete.

Coarse aggregate is well graded when the particles range from ¼ in. up to the largest size which may be used on the kind of work to be done without a considerable excess of any one size.

Photographs on page 12 show how well-graded aggregates look before and after being separated in the various sizes. Note that the smaller particles fit in among the larger ones.

The natural mixture of fine and coarse aggregates as taken from a gravel bank or crusher seldom is suitable for concrete unless first screened to separate the fine material from the coarse and then recombined in the correct proportion for the class of concrete being made. Most gravel banks contain more sand than is desirable for best results.

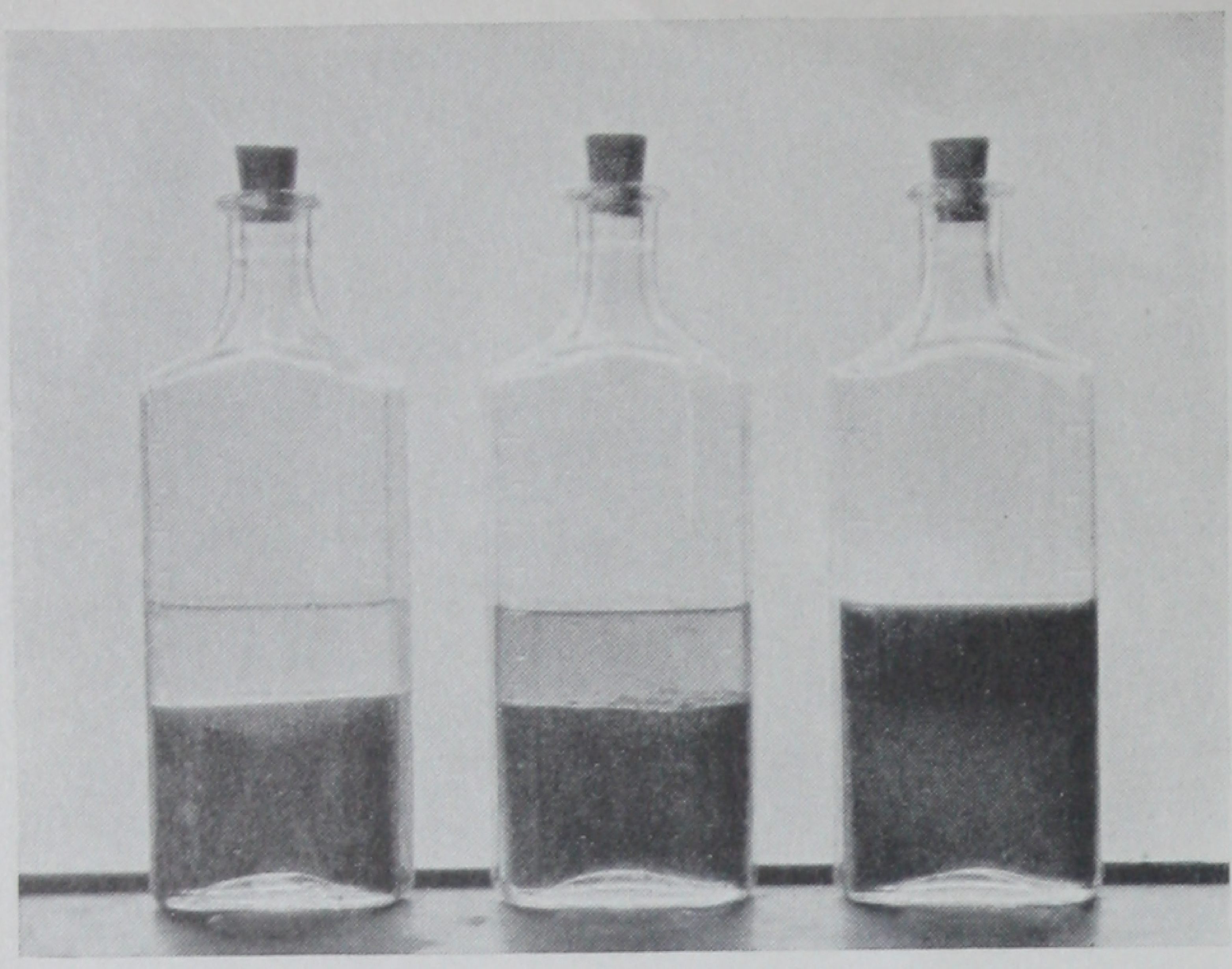


A quart fruit jar may be used to make the silt test for sands.

What is known as the silt test is used to detect the presence of too much extremely fine material. The colorimetric test is used to detect the presence of harmful amounts of vegetable matter.

Silt Test (Demonstration No. 2)

In making the silt test, an ordinary quart milk bottle or quart fruit jar is used. Fill the container to a depth of 2 in. with a representative sample of dry sand to be tested. Add water until the bottle or jar is about three-fourths full and shake vigorously for one minute, the last few shakes being in a sidewise direction to level off the sand. Allow the jar to stand for an hour, during which time any silt present will be deposited in a layer above the sand. If this layer is more than ⅛ in. thick, the sand from which the sample is taken is not satis-



The colorimetric test is used to detect the presence of harmful amounts of organic matter in aggregates. A colorless liquid indicates aggregate free from organic matter. A slightly colored liquid indicates presence of some organic matter but not enough to prove injurious. A dark liquid, as in the right hand bottle, shows that the aggregate is unsatisfactory for concrete work unless the organic matter is washed out.

factory for concrete work unless excess silt is removed by washing.

Colorimetric Test (Demonstration No. 3)

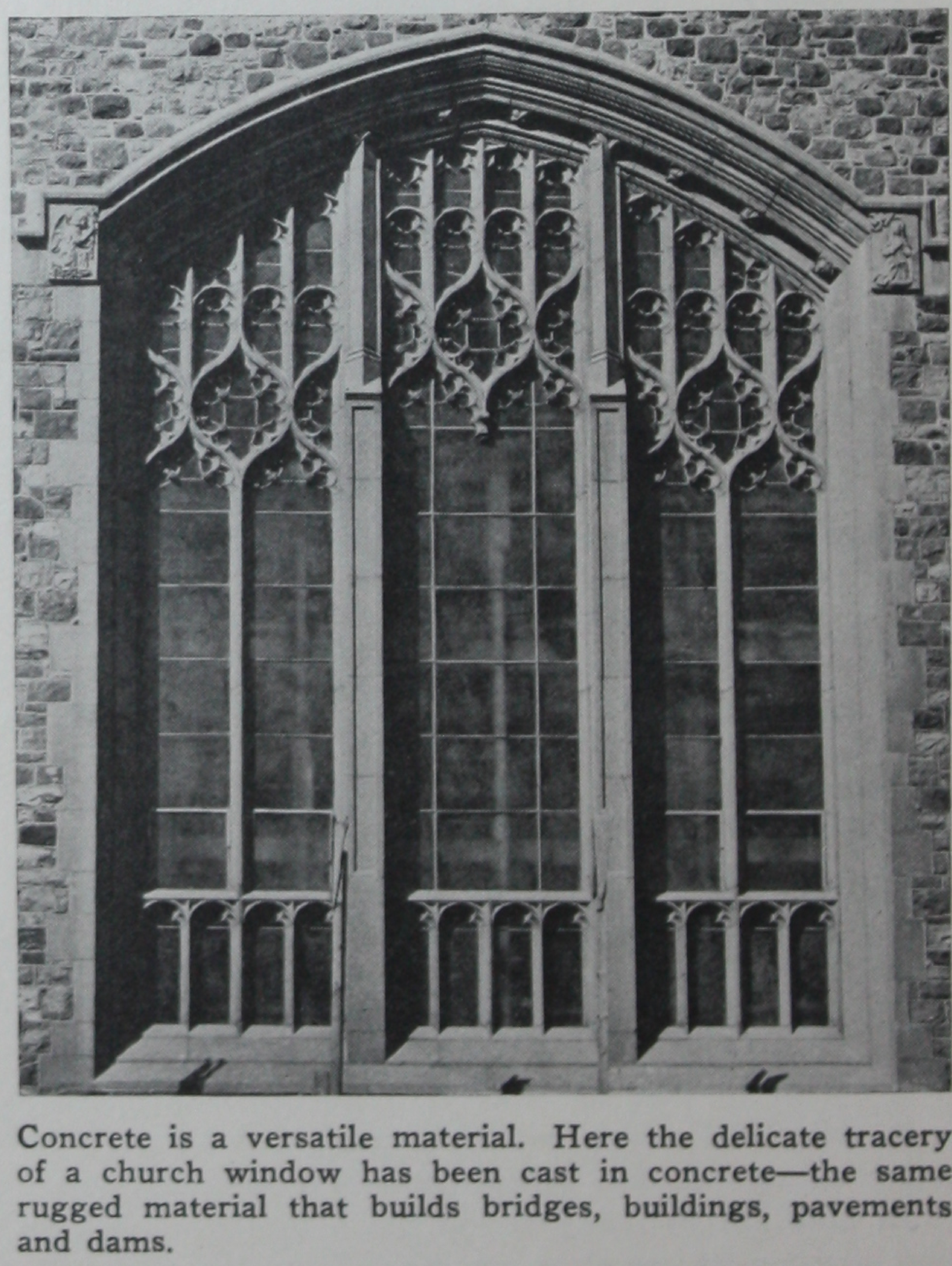
The colorimetric test is a reliable indicator of the presence of harmful vegetable matter except in areas where there are deposits of lignite. This test is particularly valuable when locating a new sand supply.

In making the test, an ordinary 12-oz. prescription bottle, such as druggists or physicians use, is filled to the 4½-oz. mark with a sample of the sand. To this is added a 3 per cent solution of caustic soda (sodium hydroxide) until the 7-oz. mark is reached. A 3 per cent solution of caustic soda is made by dissolving 1 oz. of sodium hydroxide, which may be purchased at any drug store, in a quart of water, preferably distilled. The solution should be kept in a glass bottle tightly closed with a rubber stopper. Handling sodium hydroxide with moist hands may result in serious burns. Care should be taken not to spill the solution, as it is highly injurious to clothing, leather and most other materials.

As soon as the solution of sodium hydroxide is added to the sand, the contents of the bottle are thoroughly shaken and then allowed to stand for 24 hours. At the end of this time the color of the liquid will indicate whether the sand contains dangerous amounts of vegetable matter. A colorless liquid indicates a clean sand free from vegetable matter. A straw-colored solution indicates some vegetable matter but not enough to be seriously objectionable. Darker colors mean that the sand contains injurious amounts and should not be used unless it is washed, and a re-test shows that it is then satisfactory.

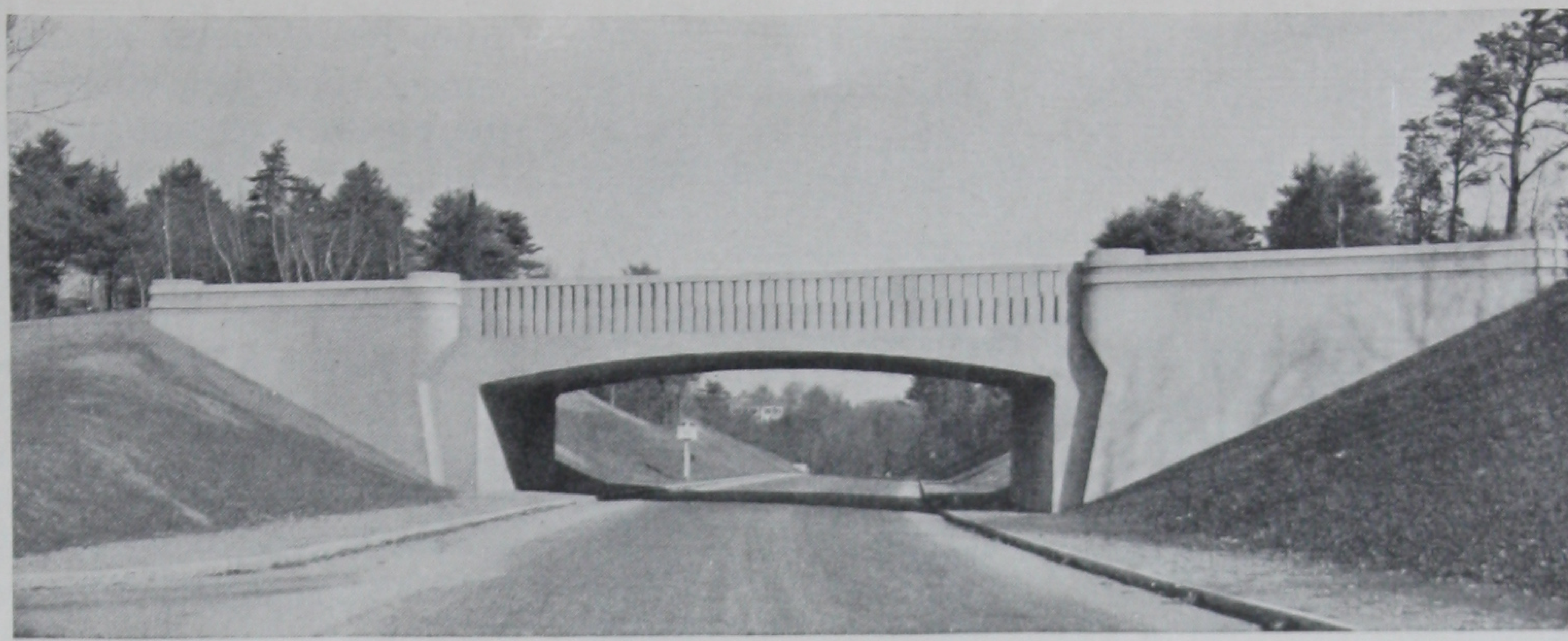
QUESTIONS

1. What is portland cement?
2. What are the raw materials used in the manufacture of portland cement?
3. How is portland cement made?
4. What is meant by "setting of cement"?
5. What is concrete?
6. What is mortar?
7. What are aggregates?
8. Why should aggregates be well graded?
9. What is bank-run gravel?
10. What are the requirements of a good concrete aggregate? What simple tests could be applied with equipment easily available in a school laboratory?
11. What is a safe rule to follow with regard to the selection of water for use in concrete?



Concrete is a versatile material. Here the delicate tracery of a church window has been cast in concrete—the same rugged material that builds bridges, buildings, pavements and dams.

Reinforced concrete rigid frame bridges are used extensively in eliminating dangerous intersections of highways or of highways and railroads. A "rigid frame" bridge is one with a flattened arch designed to give maximum clearance below.



CHAPTER III

Proportioning

ESSENTIAL PROPERTIES OF CONCRETE

THE two principal requirements of hardened concrete are strength and durability—strength to perform the functions of the structure and durability to resist exposure to the elements—and they should be the governing considerations in the design of mixtures. A third element, economy, is not as important on small jobs as either durability or strength, but becomes increasingly important as the amount to be placed increases. Still a fourth requirement is workability during placing. A successful design will achieve a proper balance among these four essentials; the mixture will be placeable in the proper degree; it will represent an economical use of the available materials; and when hardened it will provide necessary strength and resistance to weathering agencies. In the pages which follow, the detailed procedure for arriving at such a design is presented.

PRE-DETERMINING QUALITY

Quality of the Cement Paste

As previously stated, concrete is a mass of fine and coarse materials, known as aggregates, which are surrounded and held together by a hardened portland cement paste. If the paste is strong and the aggregates hard, the concrete is strong. If the paste is watertight, the concrete is watertight. If the paste and aggregates are durable, the concrete is durable.

When the materials for concrete are first mixed together, the cement and water form a paste which surrounds the particles of aggregate and holds them together in a plastic mass. A chemical action then takes place between the cement and water causing the paste to harden.

If too much water is added, the paste becomes thin or diluted and will be weak when it hardens. A paste of this kind will not hold the particles of aggregate firmly together. On the other hand, cement paste which has good binding qualities will hold the particles of aggregate firmly together to make strong concrete. Therefore, the water and cement are the important ingredients in a concrete mixture. *The potential quality of this paste is determined by the quantity of water mixed with the cement.*

Good concrete should be more than strong enough to serve its intended purpose, sufficiently durable to resist the effects of weather, and dense enough to prevent water from passing through it. Concrete having these qualities can be produced through the use of suitable materials, correct proportioning, and careful mixing, placing, finishing and curing. The direct relation between strength of concrete and the relative quantities of water and cement in the mixture is ex-

More than 100,000 miles of concrete highways carry traffic in every state in the Union. This picture shows the Coast Highway in San Luis Obispo County, Calif.

Stepping stones of concrete beside a concrete garden pool add charm to this estate.

pressed by the water-cement ratio strength law:

For given materials and conditions of handling, the strength of concrete is determined primarily by the ratio of the volume of mixing water to the volume of cement so long as the mixture is plastic and workable.

In other words, if 7 gal. of water are used for each sack of cement in a mixture, the strength at a certain age is practically fixed, regardless of what quantities of aggregate are used, *so long as the mixture is plastic and workable* and the aggregates are clean and made up of sound particles.

In the laboratory studies leading to the discovery of this principle it was found that, unless the mixtures were of such consistency that they could be readily molded into a dense, compact mass, the strength results did not conform to the general relationship. Likewise, in the studies of watertightness it was found that, unless the mixtures were easily placeable and at the same time not so fluid as to segregate in placing, no regular relationship existed between watertightness and quantity of mixing water. Segregation means a separation of the coarse from the fine materials. The need for this plastic consistency during construction is just as important as in the laboratory studies if the concrete in the structure is to have the properties for which it is being designed. True plasticity means a mixture neither too wet nor too dry. Over-wet mixes segregate in handling and those that are too dry cannot be compacted properly.

The hardening of the cement-water paste results from the chemical reactions between the water and cement. For completion, these reactions require time, the presence of moisture, and favorable temperatures. During this process of hydration, a certain amount of water chemically combines with the cement to become a part of the permanent solid structure of the concrete. To obtain plastic mixtures more water is used than can be permanently combined with the cement even with the most extended curing. A certain amount of water, therefore, remains uncombined and distributed within the paste. The space it occupies will be represented by air voids as the water evaporates. Thus, both the quantity of water used and the extent of the curing directly affect the watertightness of the paste, and through it the watertightness and durability of the concrete.

In view of the dependence of the properties of the concrete upon the quality of the paste, it will be seen that so far as proportioning is concerned the relative amounts of aggregate and cement are important only in so far as they affect the workability and the cost, provided, of course, that the mixes are truly plastic and workable.

Designing a concrete mix, therefore, consists in selecting the water-cement ratio which will produce concrete of the desired resistance to exposure and the required strength, and finding the most suitable combination of aggregates which will give proper workability when mixed with cement and water in this ratio.

Water-Cement Ratio (Demonstrations Nos. 4 and 5)

Although this principle has been in practical use a number of years, its significance is still not fully appreciated. Its importance in securing concrete of a predetermined quality justifies some classroom time in demonstrating its effect. The following equipment will be needed:

Library paste	Cement
Strips of paper	Small shallow dish
Water	Window glass about 12 in. square
Sand	

Many home owners are paving back-yard terraces with vari-colored concrete flagstones, creating "outdoor living rooms."

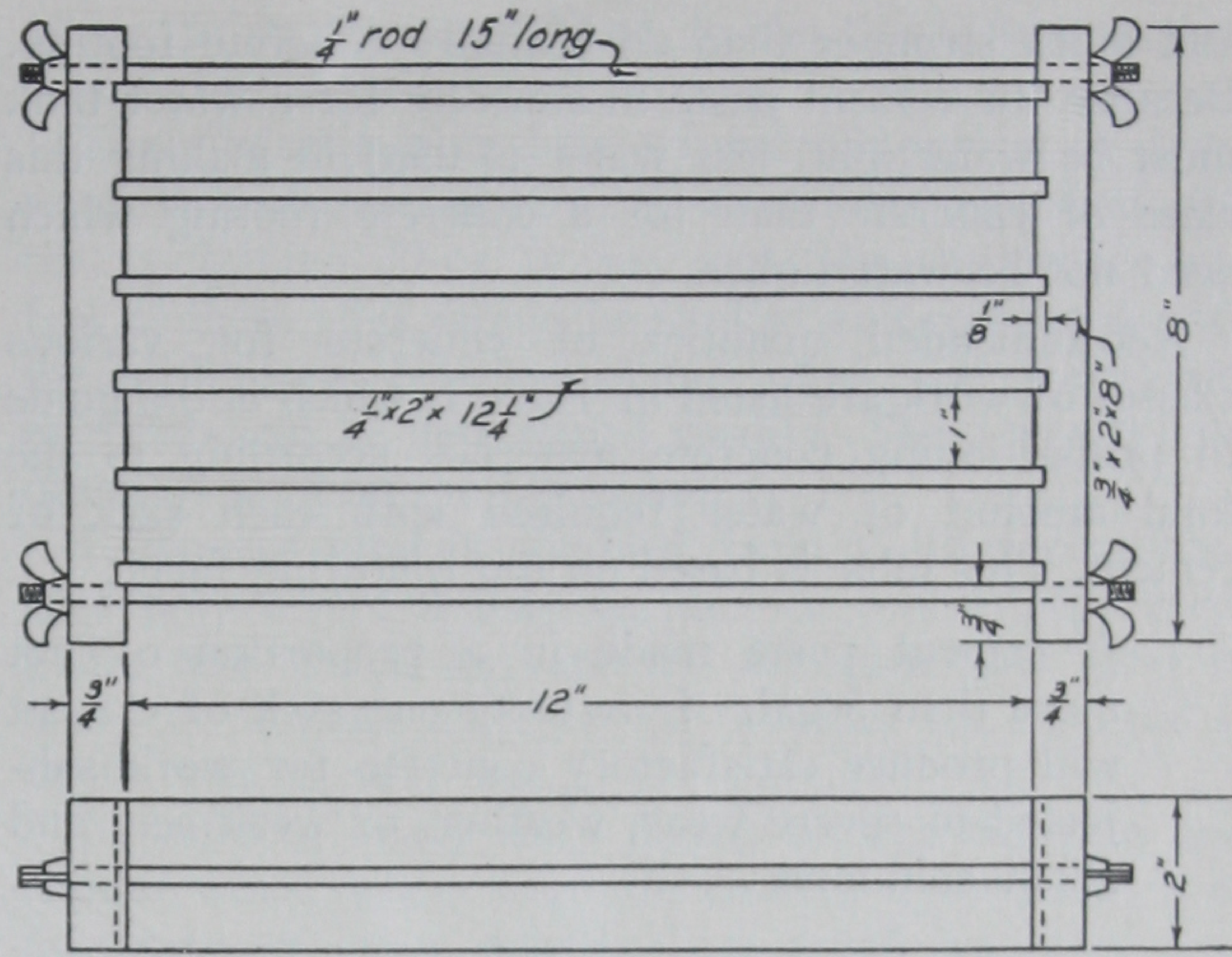
1. Take two strips of paper. Coat one end of each with library paste as it comes from the jar. Press together and note cementing property of the paste.
2. Dilute a small quantity of paste with water and make the same test with diluted paste noting impaired cementing property.
3. Mix a small quantity of library paste with sand noting the change in workability as more sand is added; mold into cube when the quantity of sand added seems to have reached the point that any additional would impair the workability. Show that strength of cube will depend upon the strength of the paste.
4. Repeat the above with diluted paste.
5. Mix 40 c.c. water and 50 c.c. portland cement into a paste and then gradually add sand to show change in workability.
6. Compare function of portland cement with other pastes and cements. Show that the strength of the concrete is dependent upon the ratio of quantity of water to the quantity of cement (gallons per sack).

The law can be further demonstrated by the use of concrete test specimens. Compression tests on cylinders will give the best results. However, equipment for testing these is usually not available in a school shop and not easily made. Beams can be used to accomplish approximately the same result, are easily made and can be tested by equipment made in the school shop.

Accompanying drawings show how to make a form for casting beams, and also how to make a device for testing them. These should be at least 1 in. wide by 2 in. in depth by 12 in. long.

Make at least four beams each with water-cement ratio varying as follows: 5, 6, 7, 8 gal. to the sack of cement. Calculate quantities carefully. Be sure to fill molds completely. Allow concrete to stand about an hour before smoothing off the top. After 24 hours, remove beams from the mold, mark them with a suitable identification and place in water for 28 days.

When dry, test each beam in the machine. Average the results of all beams made from each mix. Averages should be compared rather than individual results as considerable variation may occur. Compare breaking loads.

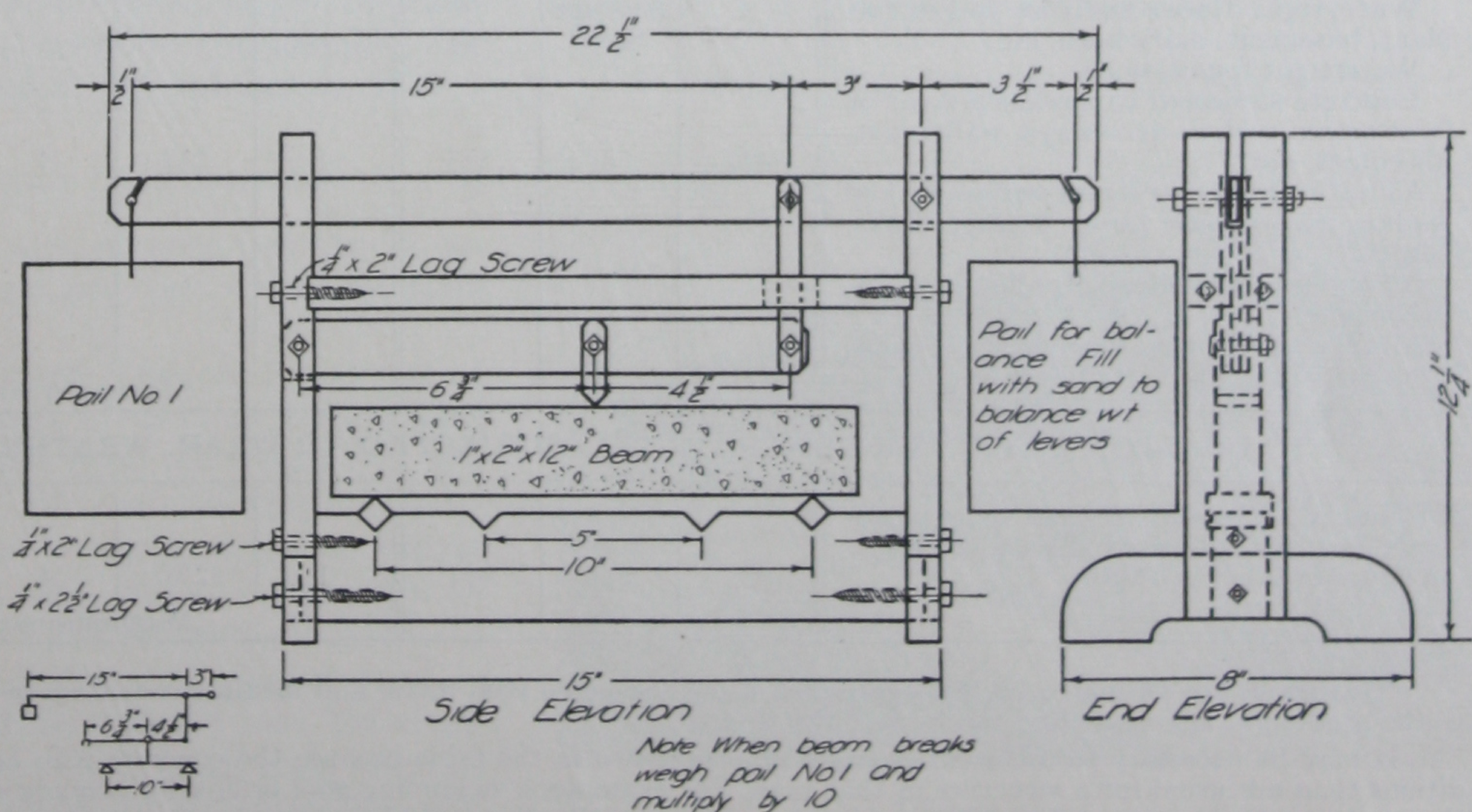


A simple mold for casting concrete beams.

Determining the Quality of Paste for Specific Uses

It is an easy matter to proportion concrete by methods which control the total amount of water mixed with each sack of cement and thus control the quality of the concrete.

Some jobs require better quality concrete than others. A concrete water tank, for example, must be watertight



A device for testing concrete beams, which can be made at home or in a school manual training department.

and much stronger than an ordinary concrete footing. Because the cement paste in concrete for a water tank must be watertight, less water is used in making this class of concrete than for a concrete footing which need not be watertight.

Recommended qualities of concrete for various classes of work are listed in Table I, which is the guide to proportioning concrete materials according to the total amount of water required with each sack of cement. This table is based on the following facts:

1. A cement paste made in a proportion of not more than 5 gal. of water to one sack of cement will produce satisfactory concrete for work subjected to severe wear, weather, or weak acid and alkali solutions.
2. A 6-gal. paste produces concrete which is watertight and is satisfactory when subjected to moderate wear and weather.
3. A 7-gal. paste will produce concrete which is suitable for use where it will not be subjected to wear, weather or water pressure.

Effect of Moisture in Sand

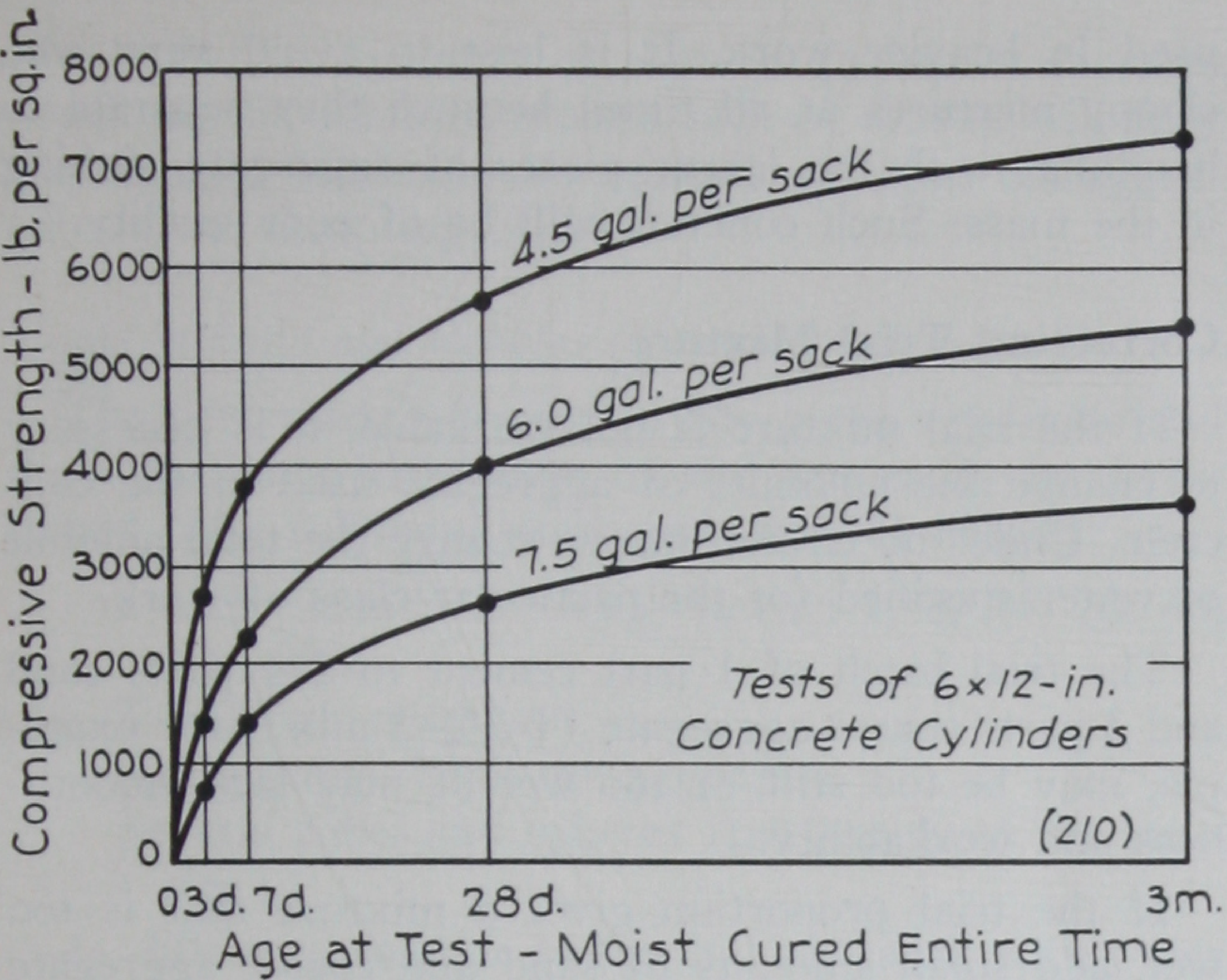
Having selected the total amount of water to be used with each sack of cement to make a paste of the quality desired, it is necessary to take into account the amount of water carried by the fine aggregate, as this moisture is free to react with the cement in forming the cement paste. The amount carried by coarse aggregate is generally so small that it can be overlooked.

TABLE I—RECOMMENDED PROPORTIONS OF WATER TO CEMENT AND SUGGESTED TRIAL MIXES

KINDS OF WORK	Add U. S. Gals. of Water to Each Sack Batch If Sand Is			Suggested Mixture for Trial Batch			Materials per cu. yd. of Concrete*		
					Aggregates			Aggregates	
	Very Wet	Wet	Damp	Cement Sacks	Fine Cu. Ft.	Coarse Cu. Ft.	Cement Sacks	Fine Cu. Ft.	Coarse Cu. Ft.
5-GALLON PASTE FOR CONCRETE SUBJECTED TO SEVERE WEAR, WEATHER OR WEAK ACID AND ALKALI SOLUTIONS									
Colored or plain topping for heavy wearing surfaces as in industrial plants and all other two-course work such as pavements, walks, tennis courts, residence floors, etc.	4¼	Average Sand 4½	4¾	1	1	1½	10	12	15
				Maximum size aggregate ⅜"					
One-course industrial, creamery and dairy plant floors and all other concrete in contact with weak acid or alkali solutions.	3¾	4	4½	1	1¾	2	8	14	16
				Maximum size aggregate ¾"					
6-GALLON PASTE FOR CONCRETE TO BE WATERTIGHT OR SUBJECTED TO MODERATE WEAR AND WEATHER									
Watertight floors such as industrial plant, basement, dairy barn, etc. Watertight foundations. Concrete subjected to moderate wear or frost action such as driveways, walks, tennis courts, etc. All watertight concrete for swimming and wading pools, septic tanks, storage tanks, etc. All base course work such as floors, walks, drives, etc. All reinforced concrete structural beams, columns, slabs, residence floors, etc.	4¼	Average Sand 5	5½	1	2¼	3	6¼	14	19
				Maximum size aggregate 1½"					
7-GALLON PASTE FOR CONCRETE NOT SUBJECTED TO WEAR, WEATHER OR WATER									
Foundation walls, footings, mass concrete, etc., not subjected to weather, water pressure or other exposure.	4¾	Average Sand 5½	6¼	1	2¾	4	5	14	20
				Maximum size aggregate 1½"					

*Quantities are estimated on wet aggregates using suggested trial mixes and medium consistencies—quantities will vary according to the grading of aggregate and the workability desired.

It may be necessary to use a richer paste than is shown in the table because the concrete may be subjected to more severe conditions than are usual for a structure of that type. For example, a swimming pool ordinarily is made with a 6-gallon paste. However, the pool may be built in a place where soil water is strongly alkaline in which case a 5-gallon paste is required.



The effect of quantity of mixing water on the strength of concrete is shown in this graph.

Table I shows how much allowance should be made for sand that is *damp, wet* or *very wet,* the amounts being based on suggested trial proportions of aggregates of the maximum sizes listed.

Dry sand is material which is as dry as it would be if it were spread out in a thin layer and dried in the sun or warm air. Such sand, which flows freely, is seldom available for concrete work.

Damp sand is that which feels slightly damp to the touch but which leaves very little moisture on the hands. Damp sand usually contains about ¼ gal. of water per cu. ft.

Wet sand, which is the kind usually available, feels wet and leaves a little moisture on the hands after being handled. Wet sand contains approximately ½ gal. of water per cu. ft.

Very wet sand is dripping wet when delivered on the job and leaves more moisture on the hands than wet sand. Very wet sand carries about ¾ gal. of water per cu. ft. and, when it contains considerable fine material, may carry as much as 1¼ gal. per cu. ft.

Measuring Moisture in Sand (Demonstration No. 6)

Whether sand is *damp, wet,* or *very wet* can be determined by the appearance and feel of materials in these conditions.

To become familiar with the appearance and feel of damp, wet or very wet sand, fill a clean cement sack about two-thirds full of sand from the supply that will be used on the job. Spread this material in a thin layer on a clean, dry floor or on heavy paper or on canvas inside a building and let it dry. Stir the sand until all surface moisture disappears and the sand flows freely.

Measure out 3 gal. of this dry sand, placing 1 gal. in each of three pans. A 2-qt. jar may be used for measuring, two jars to each pan. Then, using a prescription bottle as a measure, add 5 oz. of water to one pile, 12 oz. to another and 20 oz. to the third, mixing each thoroughly.

The pile containing 5 oz. of water is typical of *damp* sand; that containing 12 oz. is considered *wet* sand, and that containing 20 oz. is *very wet.* The appearance and feel of these piles should be studied and compared until the difference between damp, wet and very wet materials can be determined readily. The average condition of sand on the job is wet.

Whenever sand is obtained from a different source of supply where it may be finer or coarser, the foregoing test should be repeated for each new sand in order to estimate more closely whether the material is damp, wet or very wet.

In building heavy duty floors, colored concrete and similar work, where accurate control is required, it is necessary to know exactly how much water is contained in sand rather than to classify it as damp, wet or very wet. There are several methods of accurately determining the amount of moisture carried by sand. However, the following is considered a fast, accurate and simple method for use on the job:

In this method, the moisture is evaporated by burning denatured alcohol. This is done by placing a weighed sample of the sand (usually 2 lb.) in a shallow pan, pouring alcohol (about one-third cupful for each pound) over the sand, stirring the mixture and then spreading it in a thin layer over the bottom of the pan. The alcohol is then ignited and allowed to burn until consumed, the sand being stirred slowly during burning. If the sand still appears to carry surface moisture, it is advisable to repeat the burning process in order to insure drying of the sample. After burning, the sand is allowed to cool for a few minutes and is then weighed. The percentage of water is then calculated.

Suppose 2 lb. of sand, being tested for moisture content, weighed 1.9 lb. after drying. The total percentage of moisture then would be:

$$\frac{2-1.9}{1.9} \times 100 = 5.3\%$$

This sample, then, contains 5.3 per cent moisture.

Concrete locks on an Illinois canal.

Another simple method based on the same principle is to dry a sample of sand in an oven or over an open fire, heating only until surface moisture disappears. Knowing the weight before and after drying, the percentage of moisture may be calculated.

Sand containing 2 per cent moisture carries about 1/4 gal. of water per cu. ft.; 4 per cent, 1/2 gal.; 6 per cent, 3/4 gal.; 8 per cent, 1 gal., and 10 per cent, 1 1/4 gal. per cu. ft.

Determining Suitable Proportions

After the sand to be used is classified as damp, wet or very wet, depending upon the amount of water it contains, Table I may be used in determining the trial proportion for any particular job. Suppose, for example, it is desired to determine the proper proportion of materials, including water, for building a water tank. For this class of work the concrete must be watertight and be able to withstand severe exposure.

Table I specified a 6-gal. paste for concrete to be used in a water tank. However, for a trial batch using 1 part cement, 2 1/4 parts fine aggregate and 3 parts coarse aggregate, customarily designated as 1-2 1/4-3, made with damp sand, only 5 1/2 gal. are added at the mixer because approximately 1/2 gal. is contained in the 2 1/4 cu. ft. of sand. With wet sand, which is the kind usually available on the job, only 5 gal. are added. With very wet sand, only 4 1/4 gal. are added.

In making a trial batch, place in the mixer the correct amount of water, depending on the condition of the aggregates; add one sack of cement, 2 1/4 cu. ft. sand, and 3 cu. ft. of coarse aggregate; and mix all ingredients for at least one minute and preferably for two. By noting how this concrete handles and places, it can readily be determined whether changes in the proportions are necessary in remaining batches.

If the concrete in the trial batch is a smooth, plastic, workable mass that will place and finish well, the correct proportions for the job have been determined. The suitability of the proportions can be judged by working the concrete with a shovel or a trowel. The concrete should be stiff enough to stick together yet not dry enough to be crumbly. On the other hand, if the concrete is thin enough to run, it is not suitable for use. The best mixture is mushy but not soupy.

Concrete that places and finishes readily is known as workable concrete. In a workable mixture there is sufficient cement paste to bind the pieces of aggregate together so they will not separate when the material is transported to or placed in the forms. There also is sufficient cement paste and sand to give good, smooth surfaces free from rough spots, called honeycombing. In other words, there is just enough cement paste to fill completely the spaces between the particles of aggregate and to insure a plastic mix that finishes easily.

A mixture that is workable for one job, however, may be too stiff for another; that is, concrete to be placed in thin sections must be more plastic than if used in heavier work. It is best to avoid very wet, sloppy mixtures at all times because they separate in handling, with the larger pieces of aggregate sinking in the mass. Such concrete will be of poor quality.

Correcting Trial Mixture

If the trial mixture is not workable, it is necessary to change the amounts of aggregate used in the concrete. Under no circumstances change the total amount of water specified for the particular class of work.

The trial batch of 1 part cement to 2 1/4 parts sand and 3 parts coarse aggregate (1-2 1/4-3 mix), for example, may be too stiff or too wet or may lack smoothness and workability.

If the trial proportion gives a mixture that is too wet, add small amounts of sand and coarse aggregate in the proportion of 2 1/4 parts sand and 3 parts coarse aggregate until the right workability is obtained.

If it is necessary to use more sand than is shown in the trial proportions given in Table I—for instance, an extra 1/2 cu. ft. of wet sand—it is important to deduct the moisture carried by this additional sand. For the trial proportion of 1-2 1/4-3, 5 gal. of water are required to mix with each sack of cement when the sand is wet. With the addition of 1/2 cu. ft. more sand, making the mix 1-2 3/4-3, only 4 3/4 gal. of water are added at the mixer in following batches.

If the concrete is too stiff and appears crumbly, succeeding batches are mixed with less aggregate. Usually slightly less coarse material will give the required workability. Ordinarily, the first batch mixed will be somewhat stiffer than the second or third batch as some of the water in the first batch is used in wetting the mixer drum. This difficulty can be avoided by wetting the mixer before starting the mix.

PROPORTIONING FOR ECONOMY

The predetermination of quality is the first consideration in any concrete job. Regardless of cost, any work should be made of a quality in keeping with the service it will be called upon to perform. In small jobs, there may be only a negligible difference in cost; but as the quantity involved increases, it becomes increasingly important to proportion for economy. Adherence to the water-cement ratio method will control quality, but may not result in economical concrete.

To secure a dense, impervious concrete, it is essential that all surfaces of aggregates be thoroughly coated with the cement paste and all voids filled. It can be readily seen that to secure economical concrete using as little cement as possible, it is necessary to select an aggregate with as low surface area and as few voids or air spaces as practicable. Aggregates vary widely in the size of the individual particles and the gradation or proportion of each size in the mixture. Gradation affects both the percentage of voids and the total surface area.

The "yield" or quantity of a given quality of concrete which can be obtained from a sack of cement will vary accordingly. It should be remembered that the aggregate is the cheap ingredient.

Voids in Sand and Pebbles (Demonstration No. 7)

The percentage of voids in any given aggregate and the variation with change in size can easily be determined. The following equipment will be needed:

1 each—standard testing sieves: 4, 8, 14, 28, 48, 100, 200.
2—500 c.c. graduates.
3000 grams—bank run aggregate.
Several cubes and spheres (preferably of the same size).

1. Fill one graduate to the 200 c.c. mark with water and the other to the 300 c.c. mark with bank run. Pour the bank run into the water. Note that 200 c.c. of water plus 300 c.c. of bank run fall considerably short of making a total of 500 c.c. It is essential that the aggregate be poured into the water rather than the water into the aggregate. Why? 500 minus the volume of mixed water and aggregate equals the c.c. of voids (air spaces) in the original aggregate:
$$\frac{\text{c.c. voids}}{\text{c.c. aggregate}} \times 100 = \%\text{ voids.}$$
2. Screen the remaining bank run, and repeat this test with the coarse aggregate and with the fine aggregate. Tabulate all results.
3. Take approximately 1,000 c.c. of fine aggregate and screen, in turn, through the No. 8, 14, 28, 48, 100 and 200 sieves keeping separate the material retained on each screen and that passing the No. 200. It will be noted that in all specimens, the particles approach the spherical and are approximately uniform in size. The average diameter is reduced by one-half from one specimen to the next. Test each one as indicated above and tabulate the results as suggested by the following:

	1	2	3	4	5
	c. c. Water	c. c. Aggregate	c.c. agg. plus Water 1 + 2	c. c. Voids	% Voids
Passing 4 retained 8					
" 8 " 14					
" 14 " 28					
" 28 " 48					
" 48 " 100					
" 100 " 200					
" 200					
Bank run					
Coarse aggregate					
Fine aggregate					

Note the uniformity in % voids in all cases of particles uniform in size. Why? Compare the percentage of voids with that obtained with the sample of bank run.

Cubes ($v=d^3$) could be placed with no voids.

Spheres ($v=\frac{\pi d^3}{6}$) placed within the cubes would leave a uniform percentage of voids regardless of size of sphere.

Volume of cube minus volume of sphere:

$$d^3-\frac{\pi d^3}{6}=d^3(1-\frac{\pi}{6})=d^3(1-.524)=.476d^3$$

or 47.6% of total volume of cube.

Spheres arranged at random fill the space more completely. The best arrangement would still leave 35% voids regardless of the size of balls.

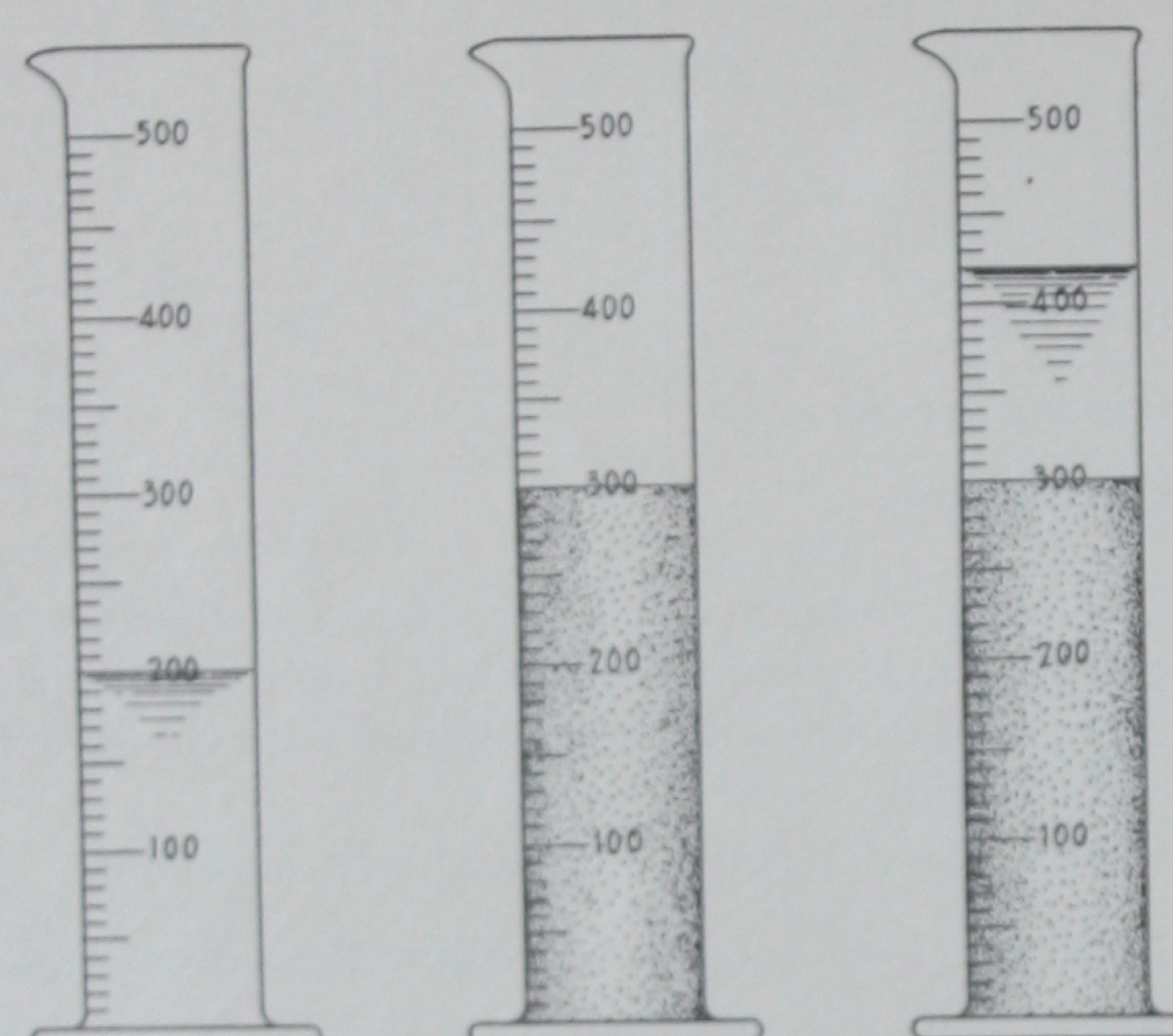
A concrete mixture in which there is not sufficient cement-sand mortar to fill the spaces between the pebbles. Such a mixture will be hard to work and will result in rough, honeycombed surfaces.

A concrete mixture which contains correct amount of cement-sand mortar. With light troweling, all spaces between pebbles are filled with mortar. This is a good, workable mixture and will give maximum yield of concrete.

A concrete mixture in which there is an excess of cement-sand mortar. While such a mixture is plastic and workable and will produce smooth surfaces, the yield of concrete will be low. Such concrete is likely to be porous.

Sand particles of uniform size which are not spherical and not perfectly arranged usually run somewhat higher.

4. Take measured volumes of various sizes and remix. Show that the total volume is considerably less than the sum of the volumes measured independently. Assuming that there should be a sufficient quantity of each size of aggregate to fill the voids in the next larger size, what mixture theoretically would give the lowest percentage of voids? Make such a mixture and determine the actual percentage of voids.



For dense and economical concrete, the aggregate should have a low percentage of voids. (See Demonstration No. 7.)

Surface Area of Aggregate (Demonstration No. 8)

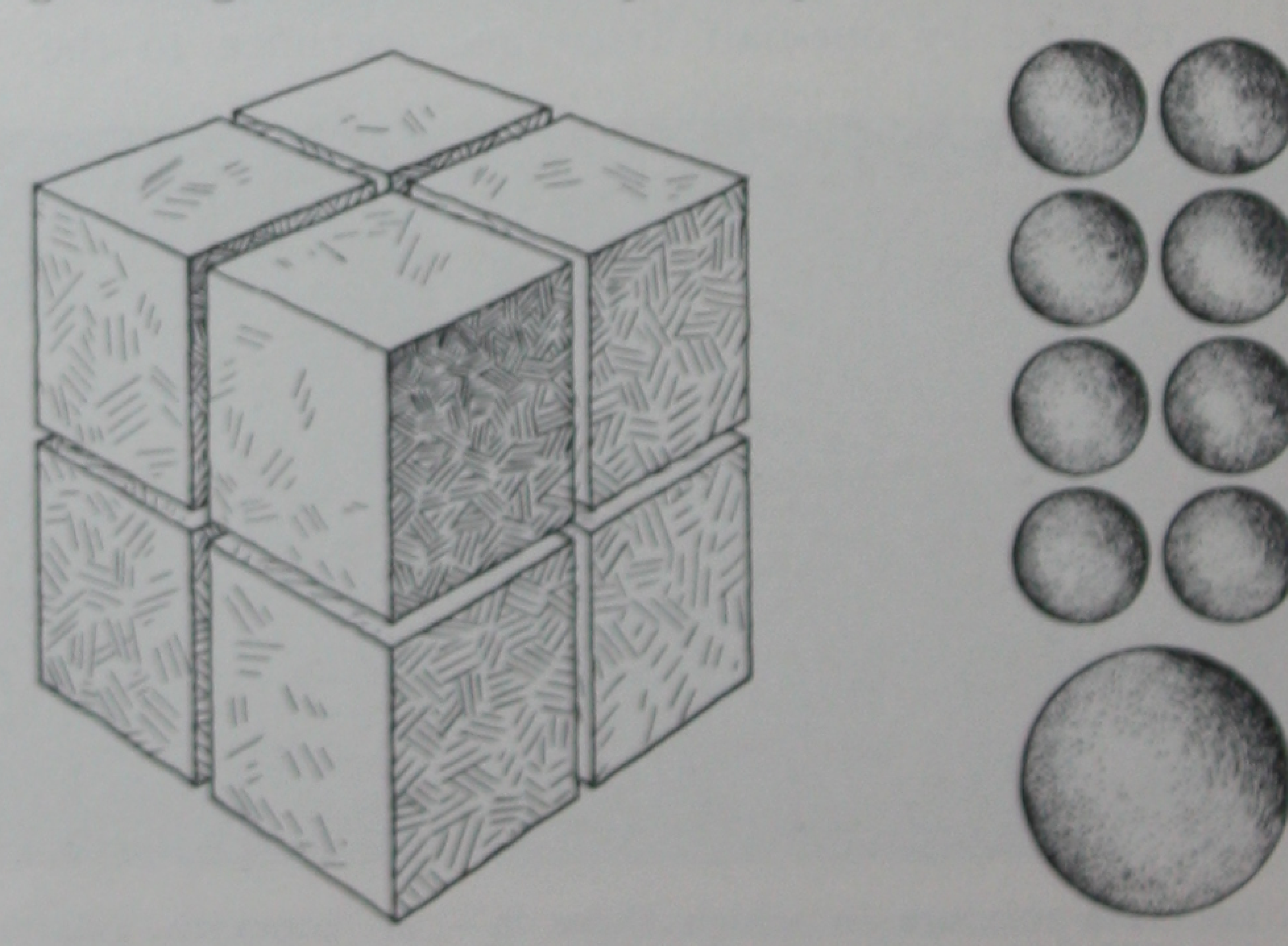
The quantity of a given quality of concrete which can be obtained from a sack of cement decreases as the surface area of the aggregate increases, since there is a limit to the total surface which can be coated with a given quantity of paste. The sieves used in demonstration No. 7 can be used here.

Is there a change in surface area as the size of individual grains varies? Which has greater surface, 100 pounds of coarse aggregate or the same weight of fine?

If the side of a cube is of a length d, the area of the surface is $6d^2$. The surface of a sphere of diameter d is πd^2. The surface of a 1-in. cube is 6 x 1 x 1 or 6 sq. in. Since eight ½-in. cubes are equal in volume to one 1-in. cube, the surface area of eight ½-in. cubes is 8 x 1.5 or 12 sq. in., which is twice the area of the 1-in. cube. Likewise, with the sphere: the area of a 1-in. sphere is $\pi(1)^2$, or 3.14 sq. in. The surface of a ½-in. sphere is $\pi(\frac{1}{2})^2 = \frac{\pi}{4}$. Again since eight ½-in. spheres are needed to equal one 1-in. sphere in volume, the surface area of an equal volume of ½-in. spheres is $8 \times \frac{\pi}{4} = 2\pi$, or 6.28 sq. in. Thus, it will be noted that each time the size of particle is reduced by one-half, the surface area is doubled. The surface area of that passing the No. 8 and retained on No. 14 is double that of the same volume passing 4 and retained on 8. That passing 14 and retained on 28 has 4 times the surface area of that passing 4 and retained on 8, etc.

From this demonstration it is apparent that in a given volume of aggregate, the larger the particles, the smaller will be the total surface area to cover. In the preceding discussion, it was shown that it is desirable to have a well-graded aggregate to reduce the percentage of voids. By combining these two principles, one would conclude that the most desirable condition would be to have a well-graded aggregate up to sizes as large as can be used effectively.

This can be shown graphically in the following manner: Using the standard sieves, screen out about a pint of each size of aggregate—that is sand passing the No. 4 sieve but retained on the No. 8; sand passing the No. 8 and retained on the 14. Take 1,000 grams of dry aggregate, each size in turn, 600 grams of cement and 300 grams of water. Mix aggregate and cement and add water. Mix thoroughly and place in slump cone tamping 25 strokes with the pointed end of a ⅜-in. rod. This cone should be made of the same proportions as the one shown on page 24 but only 4 in. high. Remove cone and observe the slump. Repeat in turn with each of the remaining sizes of aggregate. It will be noted that although the mixture with the aggregate passing the No. 4 but retained on the No. 8 sieve is decidedly sloppy, each succeeding mixture appears drier. That made from sand passing the No. 100 sieve will scarcely hold together. Why? From the preceding experiment, it will be remembered that the percentage of voids is equal in each case. This experiment also may be varied by taking 600 grams of cement and 300 grams of water, mixing these into a paste and adding sufficient aggregate to get a 2-inch slump. Compare the total amount



(Left) If a cube is cut into 8 smaller cubes, new surfaces, equal in area to the original surfaces, are formed. (Right) Although the volume of a sphere equals the volume of 8 spheres of half its diameter, the combined surface area of the smaller spheres is double that of the larger one.

of mixture obtained in each case. Now take a sample of mixed aggregate, preferably one which gave a low percentage of voids and compare the results with those just obtained.

An economical aggregate is one which is composed of particles ranging in size from the largest allowable for the job at hand down to the finer sizes. Such an aggregate will have the desirable combination of low percentage of voids and low surface area. Most natural aggregates run too fine to be economical. However, the amount of coarse aggregate which can be used is often limited by the amount of exposed surface of the concrete rather than by the economy of mixture. Coarse aggregate must be forced back from the surface. Small thin sections such as fence posts or watering tanks with large surface area in proportion to the volume require reduction of size and amount of coarse aggregate.

Selection of Aggregate Combination

In determining the proportions of materials, it is desirable to arrive at those proportions which will give the most economical results consistent with proper placing. The relative proportions of fine and coarse aggregates and the total amount of aggregate that can be used with fixed amounts of cement and water will depend not only on the consistency of concrete required but also on the grading of each aggregate.

Percentage of Coarse and Fine Aggregate in Bank Run (Demonstration No. 9)

Screen a measured quantity of bank run material, preferably 3,000 grams or more, through a No. 4 sieve. Weigh both that retained on the sieve and that passing through it, as a check. Calculate percentages. For most work there should be at least as much coarse as fine aggregate, and for some work one can profitably use nearly twice as much coarse aggregate.

Gradation of Fine Aggregate (Demonstration No. 10)

The gradation of fine aggregate can be checked with the laboratory sieves. It should be well graded and fall within the limits given below:

	per cent
Passing a 3/8 in. sieve	100
Passing a No. 4 sieve	85 to 100
Passing a No. 14 sieve	45 to 80
Passing a No. 48 sieve	10 to 25
Passing a No. 100 sieve	0 to 5

Take 1,000 grams of fine aggregate and screen through each of the above sieves in turn. Weigh each time the amount passing through the sieve and that retained upon it. Why? Calculate percentages.

It is usually desirable to get as much concrete as possible from each sack of cement; thus, the more aggregate mixed with the cement paste, the more concrete will be produced. The stiff mix contains the largest amount of aggregate and is ordinarily the most economical from the standpoint of materials.

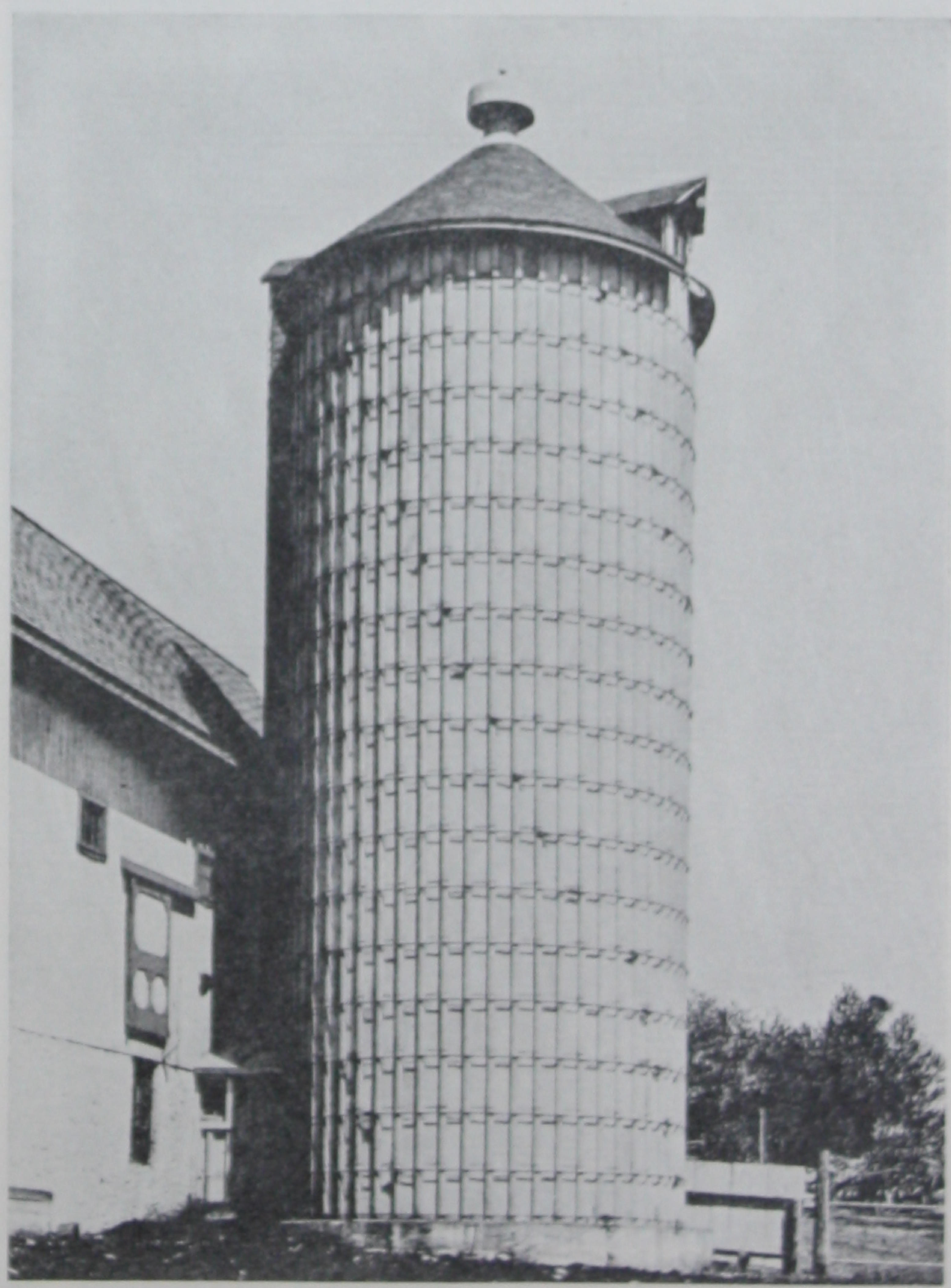
It is poor economy, however, to place a mix that is so stiff that it requires an excessive amount of labor for tamping and spading. What is saved in materials may be offset by additional cost of labor in placing and finishing.

It is desirable, then, to select that combination of sand and coarse aggregate which will produce the largest amount of plastic, workable concrete from a given amount of paste. Experience has shown that for average sand and coarse aggregate on average jobs, this proportion is approximately 40 per cent sand and 60 per cent coarse aggregate. Generally, a slightly oversanded mix is the most satisfactory.

The following recommendations will prove helpful in determining the best proportion of sand to coarse aggregate, these figures being based on materials in wet condition as they are found on most jobs:

For coarse aggregate ranging from 1/4-in. up to 1 1/2-in., use approximately 40 per cent sand and 60 per cent coarse aggregate.

For coarse aggregate from 1/4-in. up to 3/4-in., use about 50 per cent sand and 50 per cent coarse aggregate.



Silos made of concrete staves are widely used in storing feed for cattle.

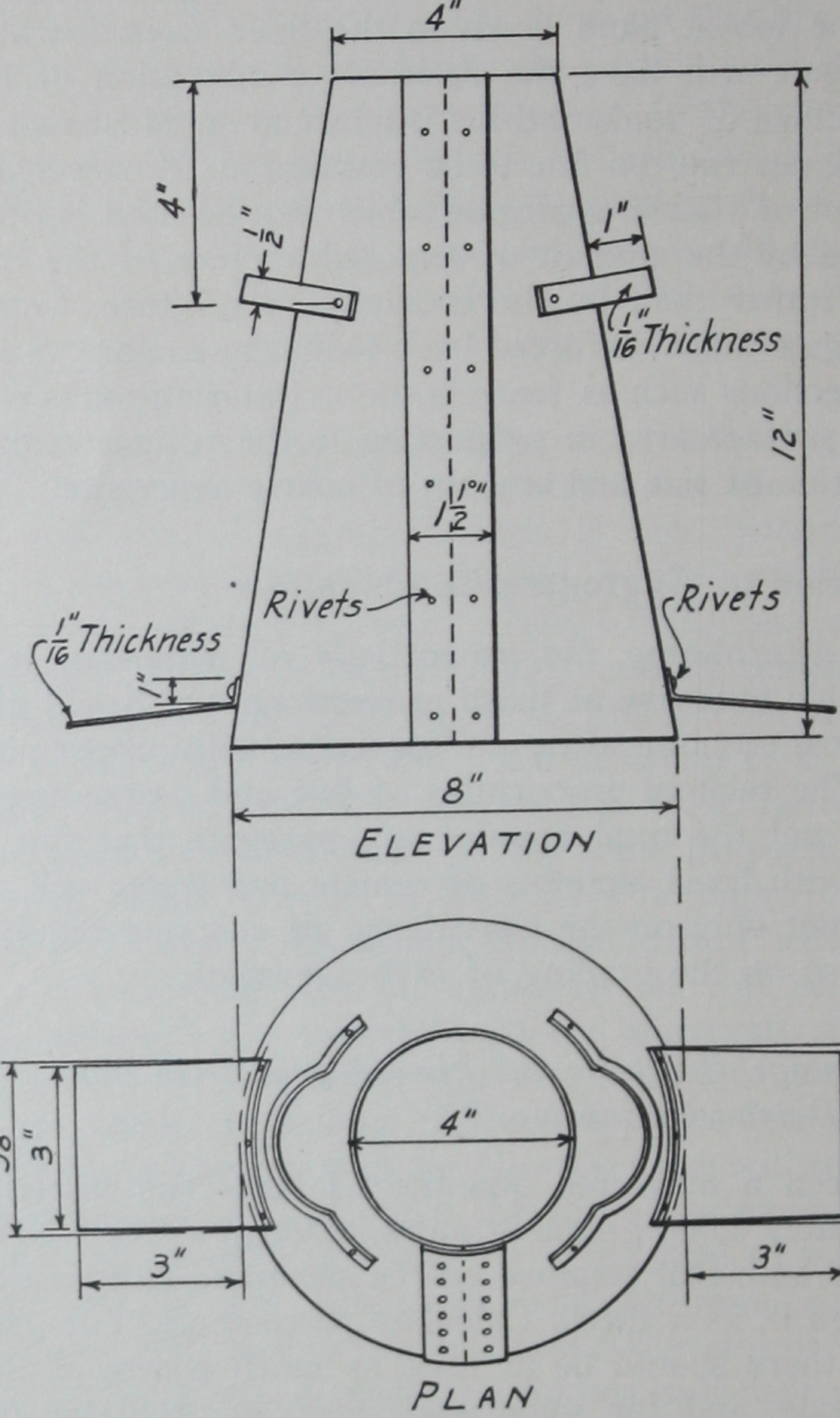
The suggested proportions given in Table I are for use only in trial batches. Each of these proportions may need to be corrected to get the best yield and the desired workability. Stiff, medium, and wet mixtures of concrete are shown on page 21. For foundations, footings, walls, pavements, and work of like character, the stiff consistency is recommended. A moderately wet mix is suitable for thin sections of concrete.

The Slump Test

The slump test may be used as a rough measure of the consistency of concrete—that is, the degree of wetness of concrete, such as stiff, medium or wet. This test is not to be considered as an exact measure of workability, and it should not be used to compare mixes of entirely different proportions or of different kinds of aggregates. Changes in the slump indicate changes in grading or proportion of the aggregates or in the water content, produced by changes in moisture content of the sand. Correction should be made immediately to get the proper consistency by changing amounts and proportion of sand and coarse aggregate, care being taken that the total amount of water specified for mixing with each sack of cement is not changed.

The slump test shows the consistency of concrete. In making this test, the concrete is compacted with a rod to make sure that it fills the cone completely.

To avoid mixes that are too stiff or too wet, slumps falling within the limits given in Table II are recommended. This table lists a few kinds of structures as typical examples for each range of slumps. The slump test is especially useful in colored concrete work.



Design of cone used in making slump test.

In making the slump test, the test specimen is made in a mold of No. 16-gauge galvanized metal in the form shown in the accompanying diagram, the diameter at the base being 8 inches, at the top, 4 inches, and the height being 12 inches. The base and top are open. The mold is provided with foot pieces and handles as shown.

TABLE II—RECOMMENDED SLUMPS FOR CONCRETE

Type of Structure	Slump in Inches	
	Minimum	Maximum
Massive sections; pavements and floors laid on ground	1	4
Heavy slabs, beams, or walls; tank walls; posts	3	6
Thin walls and columns; ordinary slabs or beams; vases and garden furniture	4	8

Slump is measured from a straightedge laid across the top of the slump cone.

When the slump test is made, the sample is taken immediately after the concrete has been discharged from the mixer. The mold is placed on a flat surface, such as a smooth plank or a slab of concrete, and is held firmly in place by standing on the foot pieces while filling it with concrete. The mold is filled to about one-fourth of its height with concrete, which then is puddled, using 25 strokes of a ⅝-in. rod, bullet pointed at the lower end. The filling is completed in two more layers, rodding each 25 times without passing the rod through the layer below, and the top struck off so that the mold is exactly filled. The mold is removed by being raised vertically immediately after being filled.

The slump of the concrete is measured, as shown in the photograph above, immediately after the cone is removed. For example, if the top of the slumped pile is 4 in. lower than the top of the cone, the slump for this concrete is 4 in.; if 6 in. lower, the slump is 6 in., etc.

Moisture and Bulking of Sand

When moisture is added to dry sand, films of water are formed on the surfaces of the particles, fluffing them apart. This causes an increase in the volume, when measured in the loose condition, much greater than the volume of water added, so that a given volume of damp sand may be the equivalent of a much smaller volume of dry sand. This bulking increases rapidly with increases in moisture content until the moisture is about 6 per cent by weight when the bulking may be as much as 20 or even 30 per cent. Further additions of water tend to flood or pack the sand, decreasing the amount of bulking. When the sand is completely inundated the volume is approximately the same as when measured dry and loose. The finer the material the more it will bulk for a given moisture content. The size of the measure and the method of filling also affect bulking, which should be evaluated for each job. Coarse aggregates are little affected in volume by moisture.

Bulking of Sand (Demonstration No. 11)

The following demonstration will help to show the effect of moisture upon bulking:

Equipment:

metric scales	graduates
dry sand	flat surface (glass or sheet metal)
water	small straightedge

Method:

1. Fill the beaker with dry sand, without shaking or tamping; strike off excess with straightedge and weigh.
2. Pour sand out on flat non-absorptive surface; add one per cent of water, by weight; mix thoroughly and pour back into the beaker. Care should be taken to fill as nearly as possible, as before; strike off excess, as before, and weigh.
3. Continue adding increments of water until the sand will not retain more. Tabulate results as below and plot on coordinate ruled paper, using per cent of dry weight as ordinates and increments of water added as abscissae.

	Weight Grams	% Dry Weight
dry		100
2% water		
4% water		
6% water		

This little test illustrates quite effectively that volume measurements of aggregate may be far from accurate.

Estimating Quantities of Materials

Information that will be helpful in estimating quantities of materials required in concrete is given in Table III.

TABLE III—ESTIMATING MATERIALS

Quantities of Cement, Fine Aggregate and Coarse Aggregate Required for 1 Cu. Yd. of Compact Mortar or Concrete

Mixtures			Quantities of Materials		
Cement	F. A. (Sand)	C. A. (Gravel or Stone)	Cement in Sacks	F. A. Cu. Ft.	C. A. Cu. Ft.
1	2	...	12	24	...
1	3	...	9	27	...
1	1	1¾	10	10	17
1	1¾	2	8	14	16
1	2¼	3	6¼	14	19
1	2¾	4	5	14	20

1 sack cement = 1 cu. ft.

Summary

From the discussion in this chapter it will be observed that the adherence to the water-cement ratio will, other factors being equal, control the quality of the concrete.

This picture illustrates the slump of stiff, medium and wet concrete mixtures.

Economy can be secured by controlling the gradation of the aggregate using as large material as can be handled on the job at hand, and a proper distribution of the various sizes.

Formerly it was customary to specify the quantities of cement, fine aggregate and coarse aggregate, e.g. 1-2-4, meaning 1 part cement, 2 parts fine aggregate, and 4 parts coarse aggregate.

This method may fail to assure satisfactory results for the following reasons:

1. It does not specify the quantity of mixing water which is so essential to the determination of strength and watertightness.
2. It does not consider the gradation of aggregate with the accompanying variation of voids and surface area.
3. It does not allow for variations in volume resulting from the tendency toward the bulking of moist sands.
4. It is often taken as the equivalent of 1-6. That is, if the user desires not to screen the bank run and remix according to recommendations, he may reason that 2 cu. ft. of fine aggregate, plus 4 cu. ft. of coarse aggregate, will equal 6 cu. ft. of bank run. This is not the case. In the first place, bank run is usually short in coarse aggregate. In the second place, the fine aggregate will fill the voids in the coarse aggregate and the total volume will be only about 5.1 cu. ft. The use of the water-cement ratio method will automatically compensate for these variations, and insure, with proper subsequent treatment, concrete of a predetermined quality. Economy can be secured by proper gradation of the aggregate.

QUESTIONS

1. What effect does the quantity of mixing water used have upon the quality of concrete?
2. Does the amount of aggregate added, or the proportion of fine to coarse affect the strength of the concrete?
3. What is the basis of the design of concrete mixtures for strength?
4. State the water-cement ratio strength law.
5. How much water would you use per sack of cement in making a watertight stock tank?
6. As applied to concrete mixtures, what is meant by consistency? Plasticity? Workability?
7. Is a workable mix the same for all types of construction?
8. Does a high compressive strength always indicate that the concrete possesses other desirable qualities in a high degree?
9. What are the principal requirements for durable concrete?
10. Is it necessary to take into consideration the water present in the aggregates?
11. Can the surface water carried by the aggregates be estimated for average conditions? How?
12. How can the correct proportions of water, cement, sand and pebbles to use in a mixture be determined?
13. What is meant by a trial mixture? How is it used?
14. How would you decide then on the amount of sand and gravel to use?
15. Should the ratio of water to cement be changed after a trial mixture?
16. Why are dry or over-wet mixes to be avoided from the standpoint of placing concrete?
17. Where mixes are to be designed for a given water-cement ratio, is the grading of the aggregate an important consideration?
18. Why is bank run gravel seldom suitable for concrete work?
19. Is a 1-2-3 mix the same as a 1-5 bank run gravel mix? Why?
20. How can bank run gravel be used?
21. Does the relative proportion of fine and coarse affect the yield, that is, amount of concrete that can be obtained with a sack of cement and a fixed proportion of water? Why?
22. How is the slump test made?

A concrete pool for water plants and fish makes an interesting addition to the garden and can be built by anyone.

CHAPTER IV

Field Control

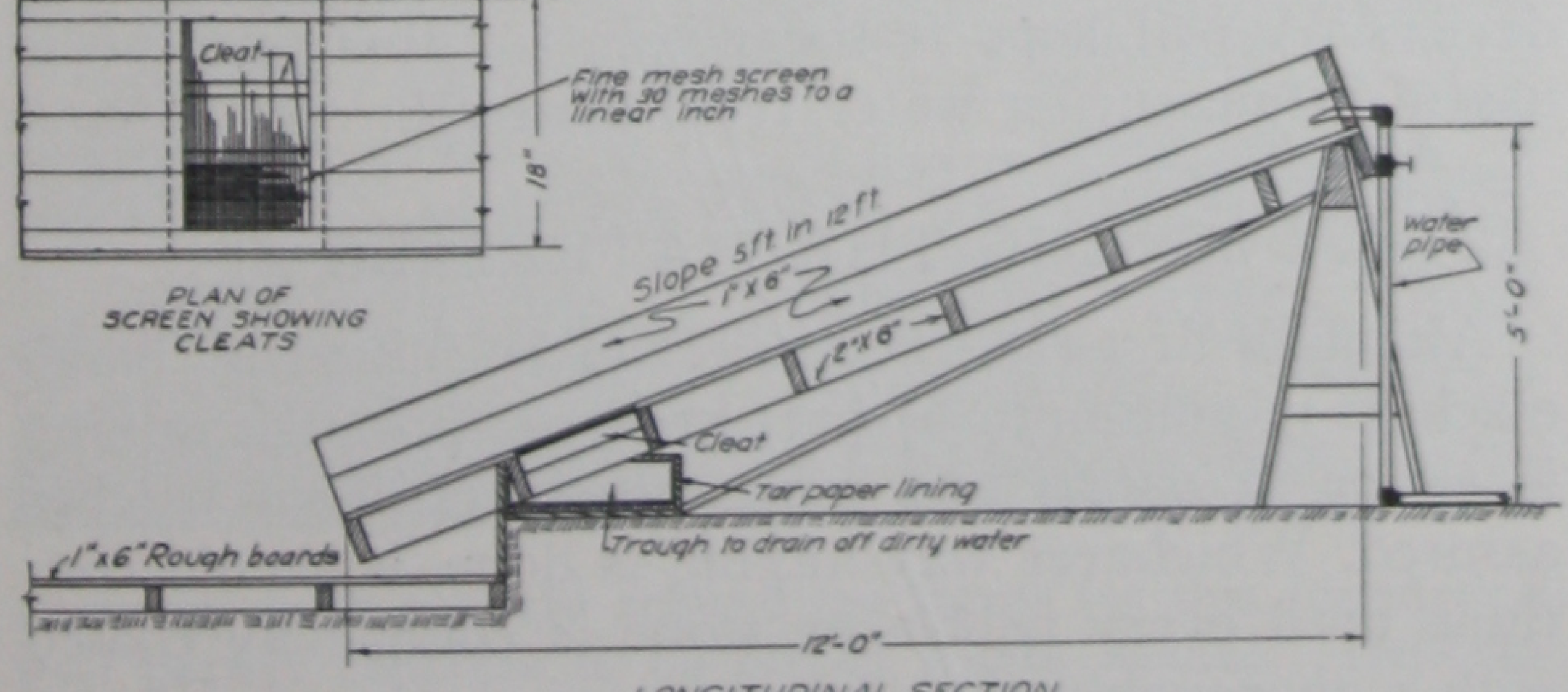
WHILE careful selection of materials and proper proportioning are necessary to assure satisfactory concrete, they are not in themselves sufficient. Field control implies not only determining the suitability of materials and the selection of proper proportions but also being sure that proper conditions are maintained throughout the work. It includes the entire process from the selection of materials to satisfactory curing, *viz.*:

Selection of materials
Measurement of materials
Mixing
Placing
Finishing
Curing

SELECTION OF MATERIALS

Before concreting operations have started, as well as during the progress of the work, it is desirable to make certain tests of the materials. Some of these relate to the suitability of the aggregates for the work, and others are necessary to control the concrete properly so that uniform batches are produced. Adjustments can be made in the mix for variations in materials.

In all tests it is important that the samples of aggregates be representative of the materials used on the job. Reducing large field samples to small quantities for individual tests should be done with care so that the final sample will be representative. This may be done by the quartering method. The aggregate sample, thoroughly mixed, is spread on a piece of canvas in an even layer 3 or 4 in. thick. It is then divided into four equal parts and two opposite parts discarded. This process is repeated until the desired size of sample remains. Several easily made tests will give a good indication of



A simple device for washing aggregates.

The "quartering" method is used to get representative samples of aggregates for testing.

the quality of the aggregate as well as its gradation. These have been described in the chapter on *Materials* and need only be mentioned here. They are:

1. Percentage of coarse and fine aggregate in bank run.
2. Gradation of the fine aggregate.
3. Silt test.
4. Colorimetric test (test for presence of organic materials).

Sand or pebbles containing injurious amounts of silt or organic matter should be washed. A simple washing device is illustrated on this page. The materials to be washed are piled on the higher end. Water is supplied by means of a garden hose, pail or other convenient means.

As the materials are washed down the incline, silt, dust and organic matter separate out and are carried away in the water. It is a good plan to run check tests to see whether washing has been thoroughly done.

MEASURING MATERIALS

All materials including water should be accurately measured to insure production of uniform batches of concrete of the quality desired. Nothing makes a good job more difficult than to have one batch mixed properly, the next one sloppy, another one harsh, and so forth during the progress of the work. Aggregates can

Steps in mixing concrete by hand. Thorough mixing is necessary to get satisfactory concrete. See text, page 29.

easily be measured by using a box made to hold exactly 1 cu. ft., 2 cu. ft. or any other volume desired. Such a box is in reality a bottomless frame. To measure the materials the box is placed on the mixing platform and filled. When the required amount of material has been placed in it, the box is lifted and the material remains on the platform. Cement need not be measured because, as already explained, each sack contains 1 cu. ft. A pail might be used for proportioning concrete. For example, a 1-2-3 batch of concrete would be measured by taking 1 pail of portland cement, 2 pails of sand and 3 pails of pebbles or stone.

Measuring can be done with shovels, observing carefully the number of shovelsful taken in handling exactly 1 cu. ft. of material. This is done by counting the number of shovelsful of each material required to fill a cubic foot box or a cement sack. This test should be made at least once each day, particularly if new loads of material are delivered on the job.

If measuring is done with wheelbarrows, each barrow should be marked on the inside for 1 cu. ft., 2 cu. ft., etc. This marking can be done by dumping a cubic-foot box or a cement sack full of material in the barrow, leveling and making a mark at that level. This can be repeated with another cubic foot of material, etc., until the barrow is calibrated.

It is probable that within a few years measurement by weight will replace the older method at least on large jobs. This method has many advantages over measurement by volume. Not only is it more nearly accurate, producing better uniformity from batch to batch, but also it is easily adjusted for necessary changes in proportions and completely eliminates the problem of correcting for bulking of sand.

In using the modern method of proportioning, that of adding a definite amount of water to each sack of cement, it is necessary to maintain accurate measurement of mixing water throughout the job.

Many concrete mixers are now equipped with tanks and measuring devices. These devices can be set to deliver any number of gallons of water into the mixer drum as specified for the work at hand. It is necessary to check water measuring equipment regularly and to see that valves are tight to insure accuracy. An ordinary 12-qt. galvanized pail, marked off in gallons, half gallons and quarter gallons, is used for measuring water when mixers are not equipped with measuring devices. A pail kept at the mixer for this purpose is useful in measuring water from a barrel.

MIXING THE MATERIALS

Although first-class concrete can be mixed by hand, machine mixing is to be preferred, as thorough mixing is easier to obtain and more nearly uniform batches assured. Whichever way mixing is done, it should continue until every pebble or stone is completely coated with a thoroughly mixed mortar of sand and cement.

Practically all of the standard batch-type machine

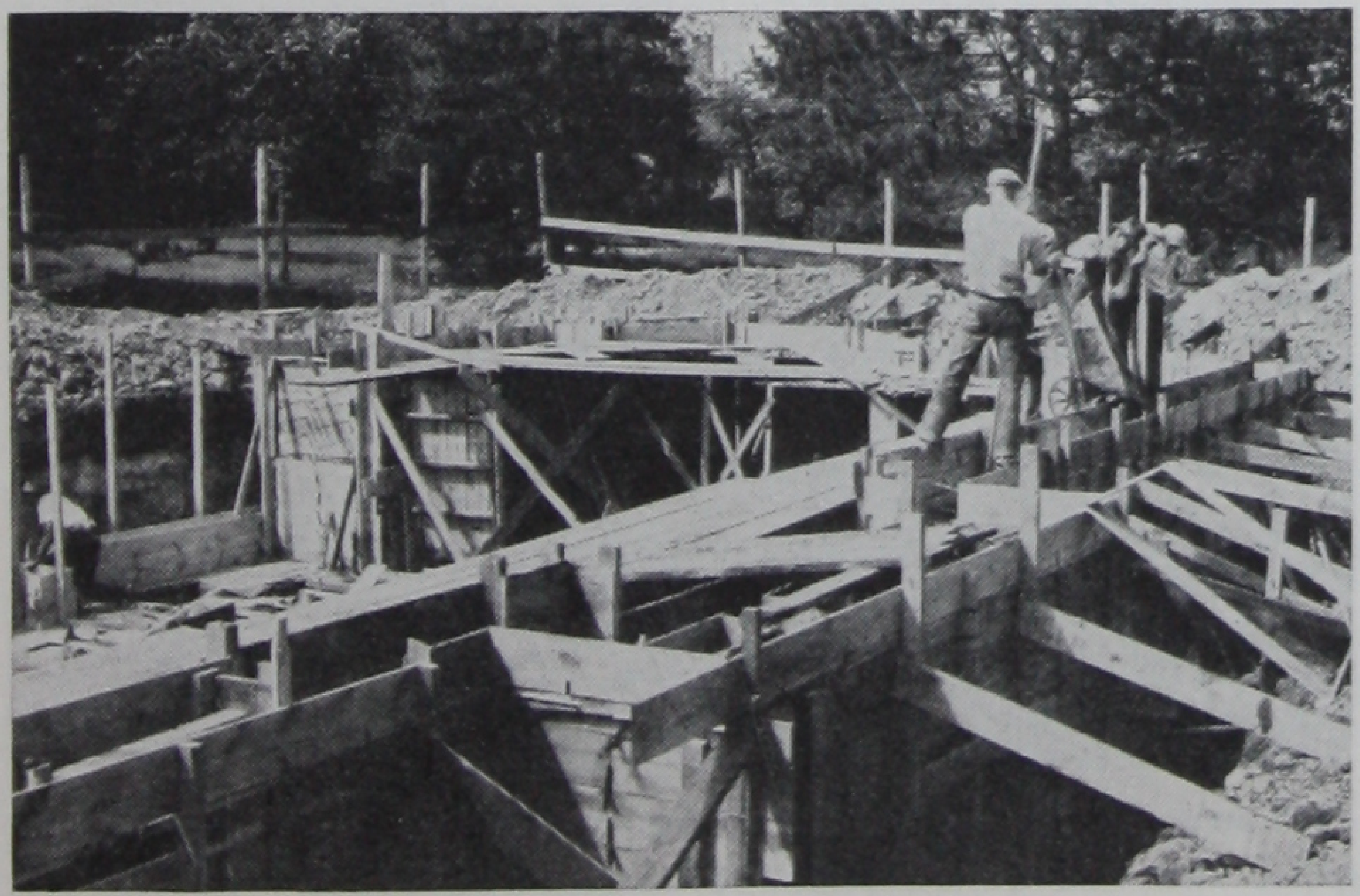
Many concrete mixers are now equipped with tanks and measuring devices which enable the amount of water in the mix to be easily controlled.

mixers on the market will render satisfactory service. In case one person may not have sufficient work to justify the purchase of a mixer, it is often possible for several to share the expense of buying a machine.

With a batch-type machine mixer it is recommended that mixing continue for at least one minute and preferably for two minutes after all materials, including water, are placed in the mixer drum.

Tests made with mixers under job conditions show a rapid increase in strength in the concrete as the mixing time is increased from 15 seconds up to about two minutes. For example, concrete mixed for about two minutes in a batch-type machine mixer is about 20 to 35 per cent stronger than the same concrete mixed only 15 seconds. More uniform concrete also is obtained from thorough mixing.

Small changes in the speed of the mixer have little effect, because thoroughness of mixing is governed largely by the time of mixing and not the rate of rotation of the mixer drum. Loading the mixer above its rated capacity is not recommended, as it prevents thorough mixing. If increased output is needed, it is best obtained by using a larger mixer or additional mixers instead of speeding up or overloading equipment.



Runways built entirely around the forms for this foundation wall permit concrete to be placed where needed. Depositing concrete evenly at all points around the wall helps prevent segregation of coarse from fine particles.

At the end of each day's run, or whenever concreting is stopped for more than an hour, the mixer should be thoroughly washed and cleaned out. This can easily be done by scouring with water and pebbles. Any caked concrete adhering to the drum or blades should be broken loose and removed.

The usual procedure in mixing concrete by hand is as follows:

The measured quantity of sand is spread out evenly on the platform. On this the required amount of cement is dumped and evenly distributed. The cement and sand are then turned over thoroughly with No. 2 square pointed shovels enough times to produce a mass of uniform color, free from streaks of brown and gray. Such streaks, when present, indicate that the sand and cement have not been thoroughly mixed.

Spading of concrete in forms forces the coarse aggregate back from the face and produces a smooth surface on the finished wall.

This mixture is spread out evenly over the platform and the required quantity of pebbles or broken stone is then measured and spread in a layer on top. The materials are again mixed by turning with shovels until the pebbles have been uniformly distributed throughout the mixture of cement and sand. At least three turnings are necessary.

A depression or hollow is then formed in the center of the pile and the proper amount of water added slowly while the materials are turned in toward the center with square pointed shovels, this turning being continued until the cement, sand and pebbles have been thoroughly and uniformly combined and the desired workability and smoothness obtained.

PLACING

Moving concrete a considerable distance after mixing and before placing is never desirable.

Methods used to move concrete from the mixer to the forms will depend largely upon the job conditions. On small jobs, wheelbarrows are the usual means of transportation. On the larger jobs, buggies and chutes are commonly used.

When using barrows or buggies, care is required to prevent segregation of the coarse from the fine parti-

Steps in finishing a patterned concrete driveway. (1) A wood float fills up the hollows and compacts the concrete. (2) The long float removes marks left by the short float. (3) The pattern is marked in the surface with a grooving tool. Any marks left are removed with a pointing trowel. (4) After the concrete has stiffened slightly, it is smoothed with a steel trowel and pattern marks are brushed to provide clean lines with smooth, rounded edges.

cles as the concrete is being moved. Segregation is likely to occur when concrete is handled over rough ground or runways. A rather stiff consistency usually is required to prevent segregation.

Concrete should be placed in the forms as soon as possible and in no case more than 45 minutes after mixing. Remove all debris and thoroughly wet or oil the forms before placing concrete.

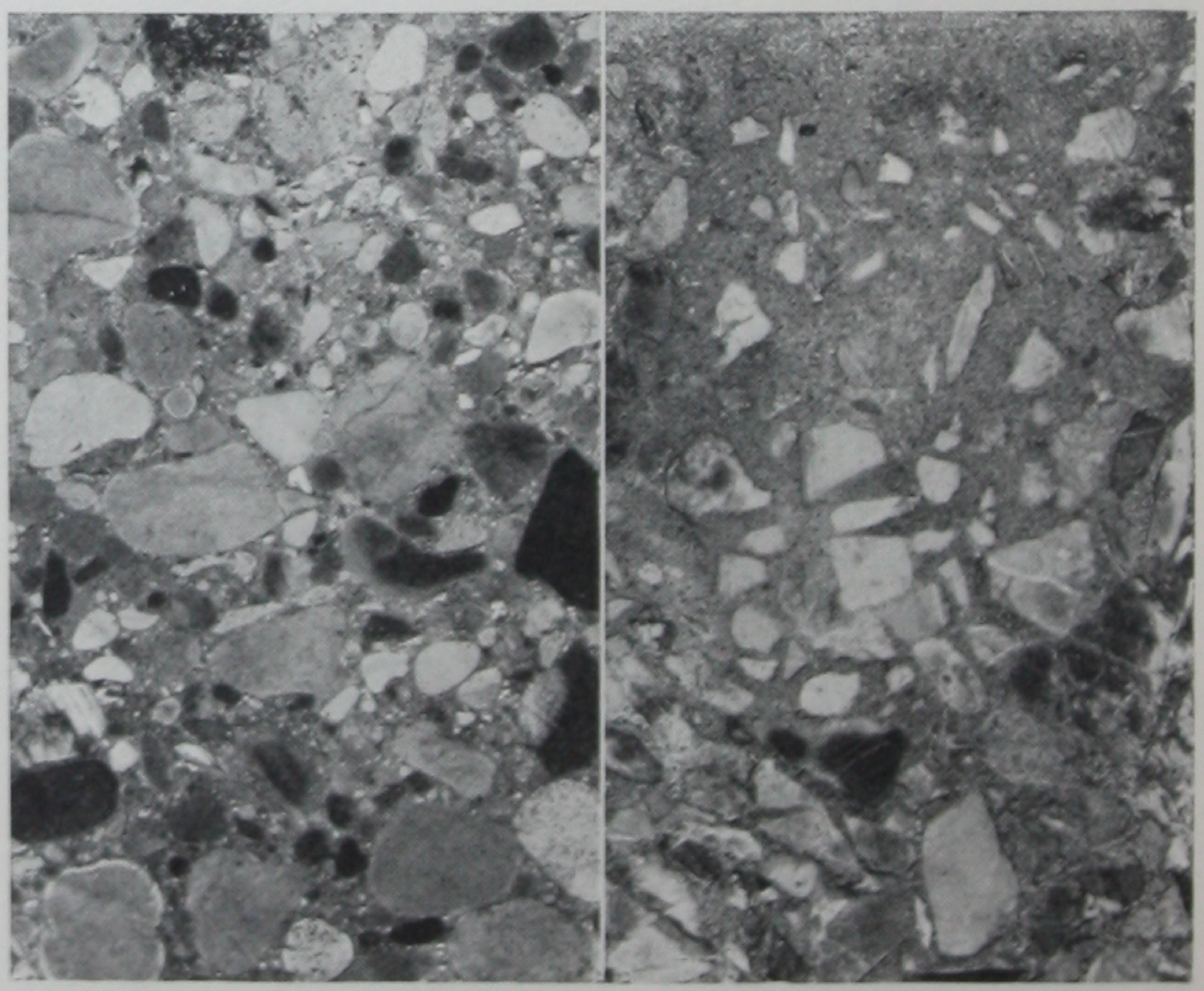
Deposit the concrete in level layers, not more than 12 in. deep, tamping and spading just enough to make it settle thoroughly and produce a dense mass. Working of the concrete next to the forms insures an even, dense surface when forms are removed.

If the mixture becomes sloppy as the forms are filled, due to water being forced out of the lower layers of concrete, stiffer mixtures should be used.

At the end of a day's run or where the work has to stop long enough for the concrete to begin hardening, roughen the top surface just before it hardens to provide a good bond for the next layer of concrete. Just before resuming concreting, clean the roughened surface and then brush with a cement-water paste of a thick, creamy consistency. This paste is applied in a thick brush coat just a few feet ahead of the concreting operation so that it does not have a chance to dry before it is covered with concrete.

This precaution to get a good bond between different layers of concrete is very important wherever the concrete construction is to be watertight.

It is just as important to prevent segregation in the forms as it is when transporting the concrete from the mixer to the forms. Depositing the concrete uniformly around the forms where it is to be used rather than placing it at a few points and dragging it or causing it



Sections cut through 6 by 12-in. concrete cylinders showing good and bad distribution of coarse aggregate. In the left cylinder, coarse particles are distributed throughout the mass; at the right, coarse aggregate has settled, as a result of too sloppy a mixture, leaving only fine particles at the surface.

to flow where needed helps prevent segregation and honeycombing.

Further care is required to see that the material flows properly into the corners and angles of forms and, in reinforced work, around reinforcement.

FINISHING

The following general information on finishing applies to the average concrete job. For *Colored Concrete* and *Special Surface Finishes,* see Chapter VII.

The concrete is struck off or leveled carefully just after it is placed in the forms. This removes all humps and hollows leaving a true, even surface for the final troweling operation.

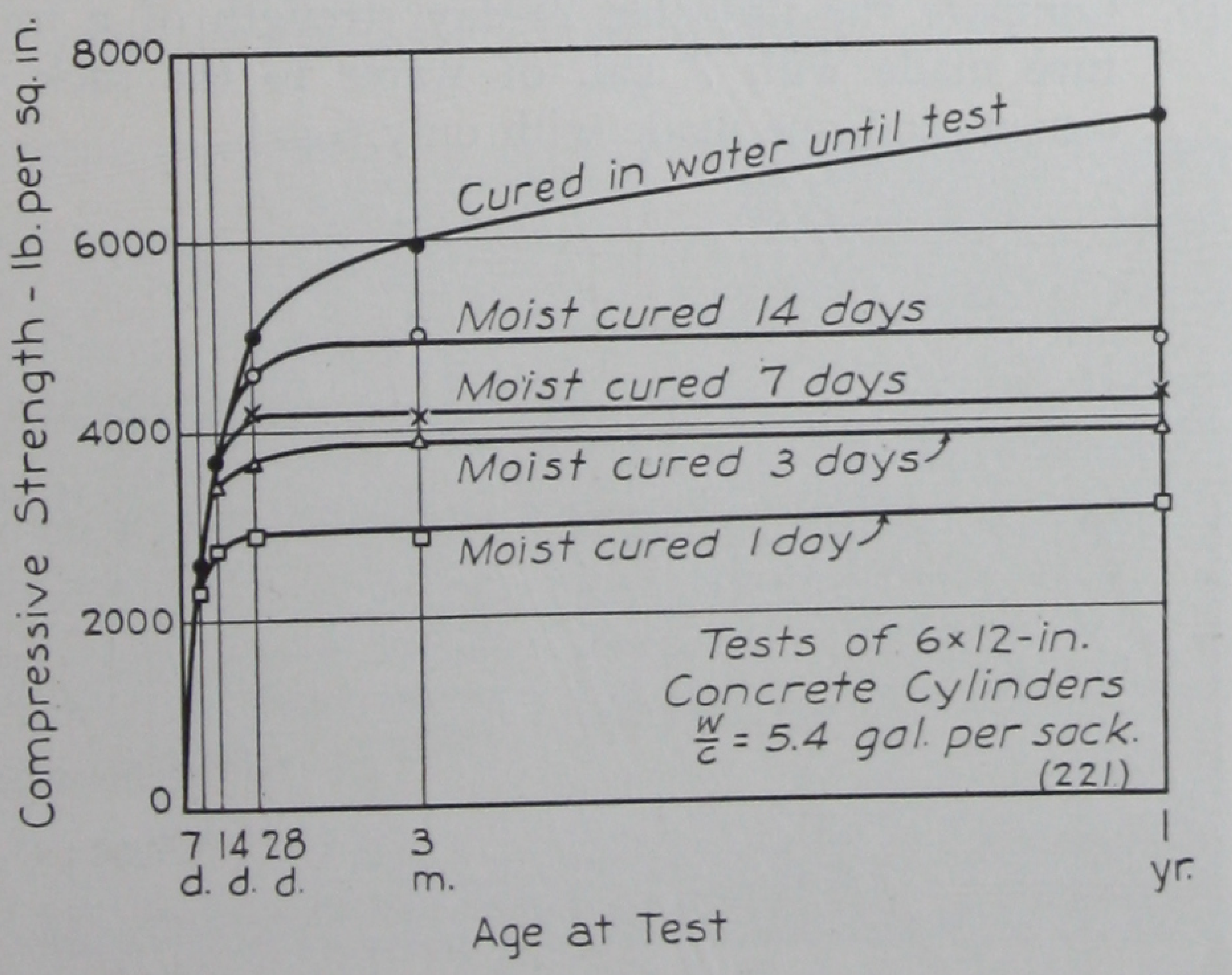
Troweling

Smooth finishes are produced with a steel trowel, care being taken to prevent too early troweling or excessive troweling, which are likely to result in surfaces that will dust or will develop numerous fine cracks called hair checks. These can be avoided by proper finishing to produce surfaces that will be dense, smooth, and which will prove durable in service.

The time of final finishing is important. If the concrete is allowed to stand until it is quite stiff but still workable, the steel trowel will compact the concrete and produce a dense surface without drawing the cement and fine material to the surface. Consequently, such finishes are usually free from objectionable dusting and hair checking.

A wood float is useful in making an even yet gritty, non-slippery surface for sidewalks, driveways and floors. Final finishing is delayed until the surface has become quite stiff. The finish produced with a wood float is commonly described as a "sidewalk" finish.

A final finish on driveways, pavements and similar work can be produced with a belt of wood, canvas or



Concrete hardens best in the presence of moisture. This diagram shows relation between curing conditions and compressive strength of concrete.

Not a swimming pool, but a concrete tennis court being cured by "ponding." Water held in place by small earth dikes keeps the concrete wet and helps it attain normal strength.

rubber, not less than 6 nor more than 12 in. wide, and at least 2 ft. longer than the width of the slab being finished. This is laid on the surface of the concrete immediately after the wood float has been used.

For the first application, vigorous strokes crosswise of the slab and at least 12 in. long are used, advancing slowly forward along the slab as the surface is made smooth and even. The second application of the belt is made immediately after the water sheen disappears, with the stroke of the belt being not more than 4 in. and the movement along the slab slightly greater than for the first belting.

Surface water should be avoided. However, when there is a small amount present, it should be allowed to evaporate before finishing. If there is considerable water, it is removed with a broom, belt, float or other convenient means. It is never good practice to sprinkle dry cement or a mixture of cement and fine aggregate on concrete to take up surface water as such fine materials form a layer on the surface that is likely to dust or hair check when the concrete hardens.

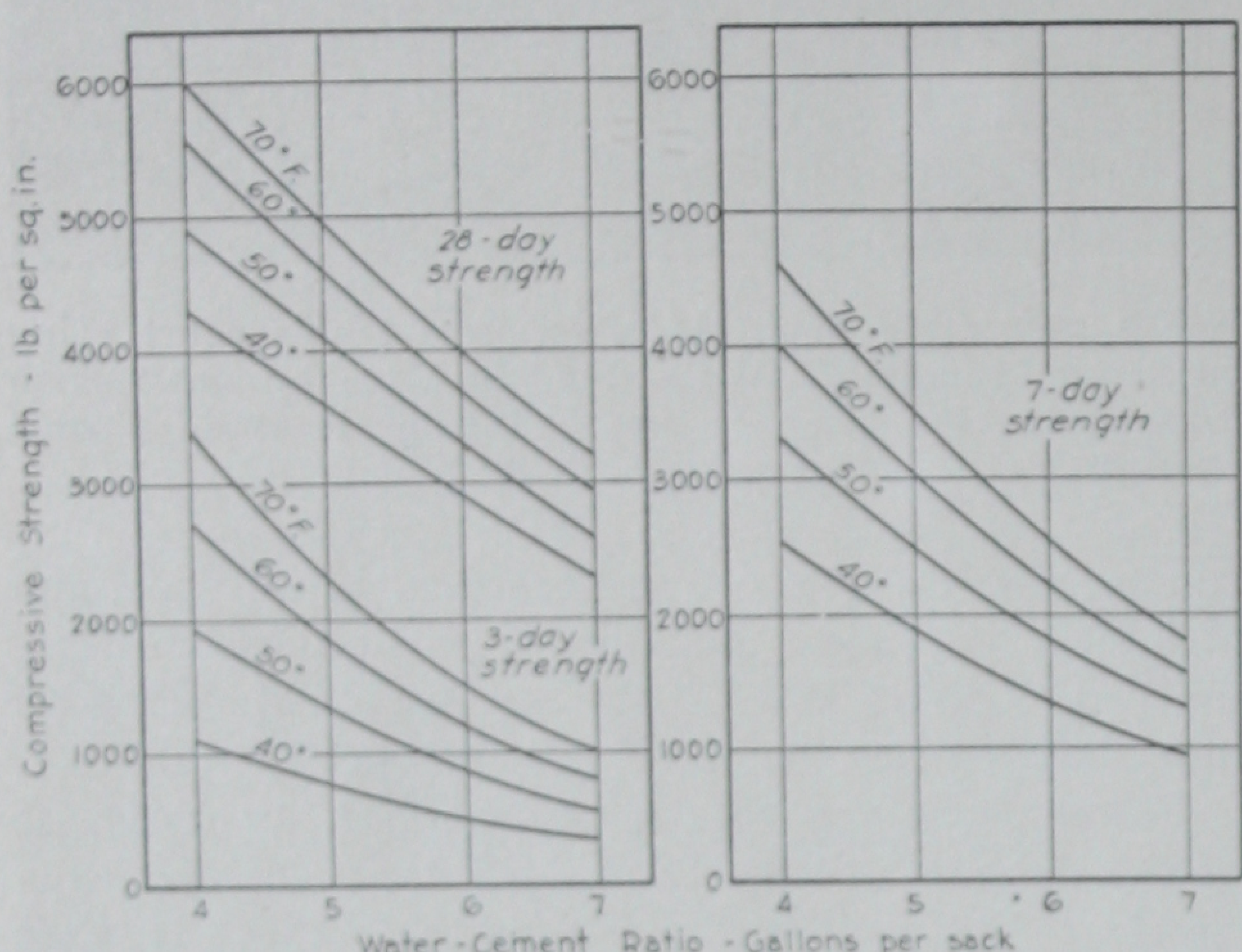
CURING

After choosing suitable materials, proportioning and mixing them according to recommended practice, and placing and finishing properly, the next step in making watertight, durable, strong concrete is to provide proper curing conditions. As previously explained, concrete hardens because of a chemical reaction between portland cement and water. This process continues so long as temperatures are favorable and moisture is present to hydrate the cement.

The desirable properties of concrete—watertightness, durability and strength—under favorable curing conditions increase with age. The increase in strength is very rapid soon after the concrete is placed, and continues slowly for an indefinite period. Tests made at various ages up to five years on concrete cured in moist atmosphere show that the increase in strength from 7 to 28 days is about equal to the increase from 6 months to

2 years. This is why it is so necessary to provide favorable curing conditions soon after concrete is placed.

Moist curing greatly increases the strength of concrete. For example, tests show that strength is increased about 50 per cent by keeping the concrete damp the first 7 days instead of letting it dry out, and keeping the concrete damp for one month increases the strength about 100 per cent over the strength of concrete kept



Concrete attains strength more rapidly if it is kept warm. The effect of temperature during the curing period is shown in this graph.

the entire period in dry air. Tests also show that heat increases the rate of hardening. Concrete cured at 70 degrees generally hardens more than twice as quickly as concrete cured at a temperature slightly above freezing. All the desirable properties of concrete are improved by proper curing.

Thorough moist curing aids in producing watertight concrete. As the cement paste in concrete hardens, additional solid matter is formed closing off the spaces between the cement particles through which water might otherwise seep. The more complete the hydration or the hardening process, the denser and more watertight becomes the cement paste.

Increased resistance to wear also is a result of proper curing, showing the importance of curing floors, pavements and other surfaces subject to wear. Continuous damp curing, particularly in the early stages of hardening, aids in securing a hard, dense surface and in preventing checking and dusting.

Wet burlap, canvas, sand or straw coverings are often used to protect newly placed concrete. The covering is placed as soon as it can be done without marring the surface. Care should be taken to keep the covering continuously wet by sprinkling. When a cover is not used, wetting of the concrete should be begun soon as possible after finishing and the surface should not be permitted to dry during the curing period. Floors, sidewalks, pavements and other flat surfaces require careful attention as moisture is lost very rapidly by evaporation due to the relatively large exposed surface.

Ponding is a good method of curing for flat surfaces. With this method, the surface to be cured is surrounded by small earth dikes and then kept flooded with water for several days.

Walls and other vertical surfaces can be protected by leaving the forms in place temporarily, or by hanging canvas or burlap over them. Such coverings are kept constantly moist by sprinkling. Curing should continue for at least 7 days, and for longer periods when it is practical to do so.

Protecting concrete in cold weather, to prevent freezing and to insure proper curing, is discussed under *Cold Weather Construction,* page 36.

QUESTIONS

1. Can good concrete be made by hand-mixing?
2. When is the batch thoroughly mixed?
3. For how long should the batch be mixed in a machine mixer?
4. Is the time of mixing of any importance?
5. What precautions should be observed when placing concrete?
6. What effect does spading concrete have?
7. What is meant by finishing concrete?
8. What are some ways concrete may be finished?
9. What is the effect of temperature on the rate of hardening of concrete?
10. Estimate quantity of materials for a sidewalk 3 ft. wide, 4 in. thick and 100 ft. long—1-2¼-3 mixture.
11. Estimate quantity of materials for foundation for a poultry house, 30 ft. by 30 ft. Six-inch wall, average 4 ft. high—1-2¾-4 mixture.
12. What is meant by curing of concrete and what conditions are necessary for proper curing?
13. How can uniform concrete be obtained?
14. How can segregation be prevented?
15. Compare the probable 28-day strength of a mixture made with 7 gal. of water to the sack of cement and one made with only 6 gal.

On walls and other vertical surfaces, forms should be left in place for several days to prevent concrete from drying out too rapidly.

CHAPTER V

Forms and Form Making

CONCRETE, being plastic at the time of mixing, can be made to conform to almost any desired shape. The degree of success with which this may be accomplished will depend very largely upon the forms used. Forms are the molds or receptacles in which the concrete is placed, so that it will have the desired shape when hardened.

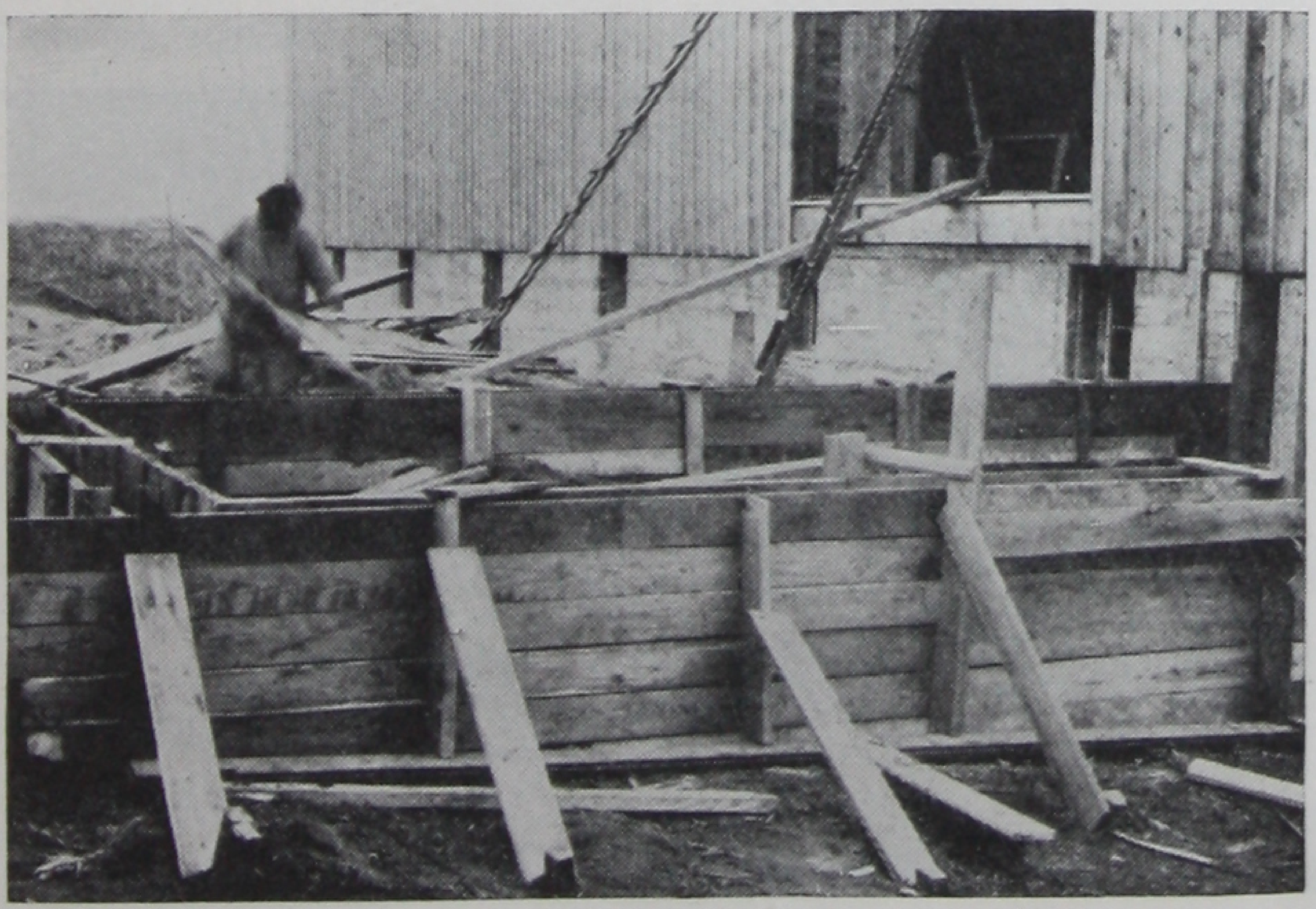
FORM REQUIREMENTS

Correctness of shape and size is the first requirement of forms for concrete. This may at times seem difficult to attain as the form must be made just the reverse of the object to be cast. Finished concrete will have no smoother surface than the forms.

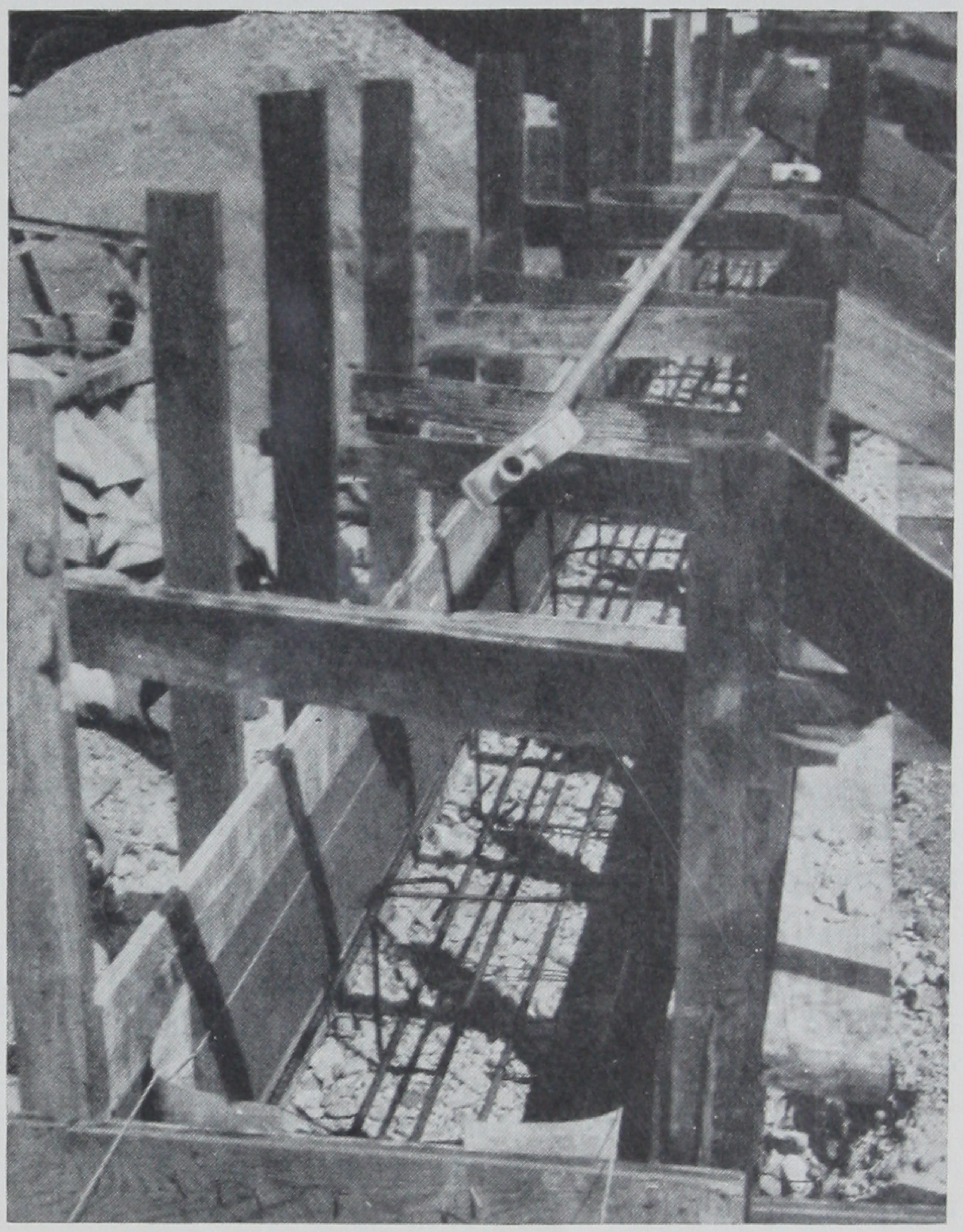
Forms must be substantial enough to retain the correct shape when filled with wet concrete. Concrete, being fluid and heavy, exerts great pressure on the forms. It is not sufficient that they be strong; they must also be rigid. Disappointment will result if one finds after concrete is placed, that the forms are deformed by resulting pressures.

The forms must be tight. The escape of the water-cement paste from small openings will change the character of the remaining mixture. Forms should be easily filled and easily removed after the concrete has hardened. Double headed nails or screws which can be withdrawn readily will greatly assist in removing forms without damaging the new concrete enclosed by them.

Forms should also permit spading the concrete to improve the character of the surface.



Concrete forms must be accurately made and be sufficiently substantial to retain their shape when filled.



Forms may be lined with building paper or other materials to produce smooth wall surfaces.

Particularly when used only once, forms should be reasonable in cost. Greater care or expense may be justified when the work is more elaborate or the forms are to be used a number of times.

MATERIALS AND CONSTRUCTION

A number of materials are suitable for the construction of concrete forms. Individual requirements will, in a measure, be the determining factors. Only a few general considerations can be listed here.

Wood

Any good, sound lumber, free from knots and decay, is suitable for form work. The use of sheathing lumber dressed on one side and both edges is recommended, because forms built of it are easy to remove. Where smooth, true surfaces are required, it is best to use

Forms built in sections are easily erected and may be used many times.

lumber that is dressed on all four sides. Tight joints are obtained by using tongue-and-grooved stock or shiplap. To prevent waste, lumber is bought in the nearest commercial length to the height or length of the forms.

The sizes of lumber commonly used in form work are: 1-in. stock for floor, foundation and wall forms, columns and beam sides; 2-in. for beam bottoms and heavy concrete construction; 2 by 4-in. for form studs, column yokes and framing for panels; 2 by 6 or 2 by 8-in. for stringers and joists; 3 by 4 or 4 by 4-in. for posts, struts, shores, uprights and sometimes for stringers; 1 or 2-in. for cleats; and 1 by 6-in. for cross ties and similar bracing.

Forms may be built in sections or panels so constructed that they can be easily removed and used again, or so that the lumber in them can be used in other work.

Forms often can be assembled in part by clamps and wedges, and only a few nails partly driven will be needed. Metal pans, adjustable shores and wire ties are other accessories commonly used. A steel wrecking or stripping bar is a useful tool for stripping wood forms from the finished concrete.

Metals

Steel, cast iron and other metals make excellent forms for concrete and are used extensively where forms can be used many times. These may be in the nature of units such as wall panels which can be assembled in a variety of shapes or in special forms for units such as blocks, ornamental vases, etc. As such forms are practically indestructible, the cost per unit cast may become quite small as the number cast increases.

Synthetic Materials

Certain hard boards made from cellulose fibres are now available. These are hard, smooth and may be obtained in larger pieces than lumber. With proper workability and manipulation of the concrete they impart a smooth surface; with such forms it is possible to secure an area as large as four feet by twelve or more, unbroken by lines from splices or cracks. Some of these materials, impregnated with oil at the factory, may be used many times.

Such forms must be carefully supported or used inside wood forms. Without such support, the bulging resulting from pressure of the concrete often becomes objectionable.

Earth

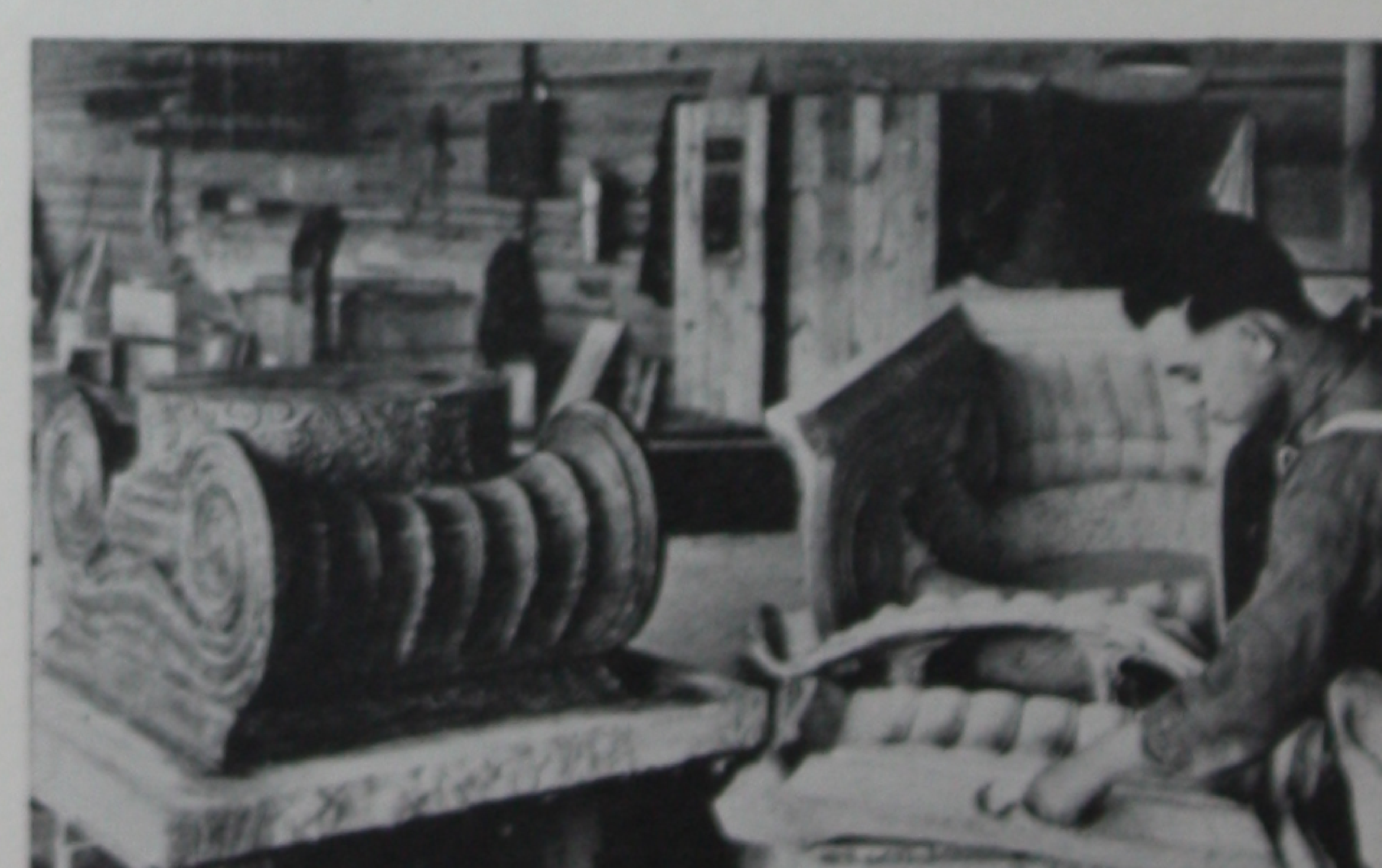
For foundation work below ground level, forms will not be necessary if the earth is so firm that the sides of the excavation will stand without caving. When placing and tamping the concrete, however, care must be taken not to knock down the earth into the concrete, as this will cause weak and porous spots in the wall. Earth cores are often convenient for forming the inside of watering troughs, bird baths, etc.

Plaster, Glue, etc.

In ornamental work, where the making of complex shapes is necessary, glue, plaster, and special molds are employed. Considerable skill is required in their preparation and use. With either of these materials it is possible to duplicate intricate designs. With glue, one can make forms for casting objects which are undercut in character, that is, so formed that it would be impossible to remove a rigid form. The glue remains sufficiently plastic to bend when removing, but is rigid enough to hold its shape when concrete is being placed.

CARE AND USE OF FORMS

To prevent adhesion of concrete and to make form removal easy, it is customary to oil form faces which come in contact with concrete. Crude oil, oil drained from crank cases or soft soap is generally used and is applied with swab or brush. The sludge can be removed from crankcase oil by settling and pouring off the clear oil. Whitewash is sometimes used instead of oil or soap.



Concrete reproduces with exactness the minute details of plaster and glue molds.

Forms are cleaned and again oiled each time before re-using. Dry, untreated wood forms will absorb an appreciable quantity of water from the concrete, often leaving the surface too dry for best results.

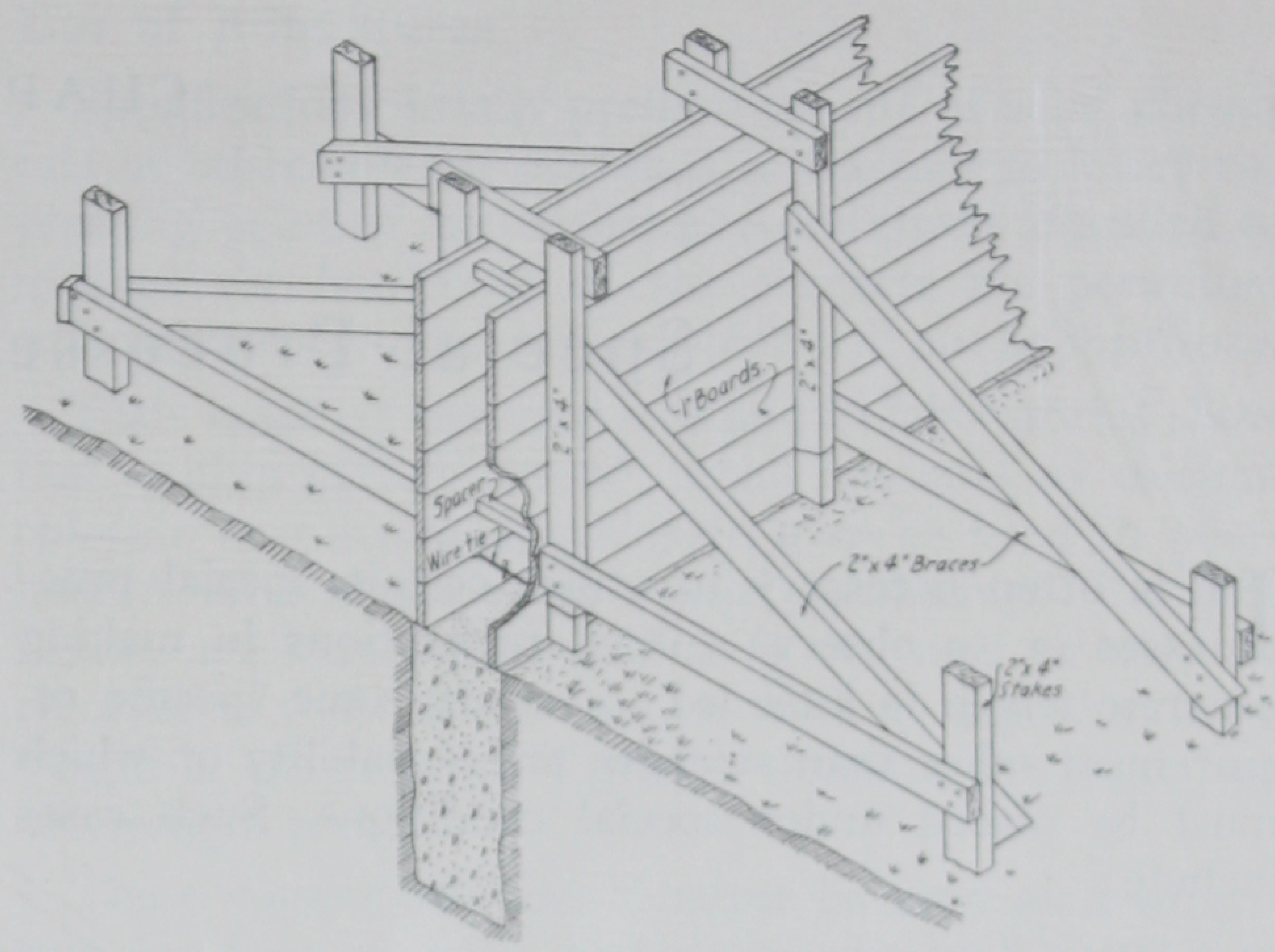
Oil, whitewash and similar materials should not be applied to surfaces of forms that come in contact with concrete that is to be painted or stuccoed.

Where construction requires the installation of conduits, pipes and other service leads, these should be put in position before concrete is placed.

After forms are made they should be well braced in position to prevent bulging of the wet concrete while it is being tamped into place. Wood spacers should be used for walls to hold opposite form faces the correct distance apart. Wire ties, passed through or around form studs and across the space between forms, tighten the forms against the spacers and hold them in true alignment so that the finished wall will be straight and even in thickness.

Wire ties are tightened by twisting. Spacers must be removed as concreting progresses, as otherwise a permanent blemish in the wall will result.

Careful building of forms is the first step in obtaining a satisfactory concrete job.



Wood spacers and wire ties hold foundation walls the correct distance apart.

In summer weather, wall forms generally can be stripped after one or two days and in colder weather in from four to seven days. Forms for concrete floors, roofs and other similar construction are left in place at least seven days in summer and fourteen days in cold weather. Forms must never be removed until it is certain that the concrete has hardened sufficiently to be self-sustaining.

QUESTIONS

1. What are forms?
2. Is form building important? Why?
3. How are forms treated so as to prevent the concrete sticking and to make their removal easy?
4. What precautions are taken when building forms so that they will keep in line and in shape when subjected to the great weight of concrete?
5. When can the forms be taken off of concrete?
6. Name five characteristics of good forms.
7. What are wire ties and their purpose in forms?
8. How would untreated dry lumber forms affect the quality of the concrete?

CHAPTER VI

Special Processes and Precautions

IT is often necessary to utilize certain special processes or to observe special precautions in making concrete which is intended to satisfy some specific requirement other than strength and durability or which must be placed under special conditions. Such cases include:

- Watertight construction.
- Cold weather placing.
- Cyclopean concrete.
- Light weight concrete.
- Gunite.

WATERTIGHT CONSTRUCTION

Watertight construction will result when the concrete itself is made watertight and when workmanship is such that all seams and other construction joints will resist the passage of water. Leakage through concrete walls often is due to openings in construction joints rather than to the lack of watertightness in the concrete itself. How to make watertight seams is discussed under *Placing*, pages 29 and 30.

One of the main reasons for making concrete watertight is that moisture entering concrete may result in structural defects. For example, the water may freeze and break the bond between the cement paste and aggregates, thus lowering the quality of the concrete. Watertightness adds to strength and durability.

Durable aggregates, completely coated with a cement paste that resists the passage of water, are necessary for watertight concrete. Leakage through concrete, if any, usually is through the paste, and can be prevented by having a sufficient quantity of watertight paste to coat all particles of aggregate and to fill all spaces between them. To produce a watertight paste, use not more than 6 gal. of water for each sack of cement, allowing for moisture in the aggregates.

To be sure that concrete will be watertight, it is necessary to have a plastic, workable mixture that can be thoroughly spaded to fill the forms without segregation of the materials. Thorough mixing, therefore, is required. This produces uniform batches, completely coats the aggregates with cement paste and makes the concrete more plastic, thus making placing easier.

Use methods of handling that will permit the concrete to be transported and placed without segregation of the materials and continue placing without stopping if possible. Where interruption cannot be avoided, special precautions should be taken to obtain good bond with the hardened concrete. (See discussion of *Placing*, pages 29 and 30.)

Favorable curing conditions are essential. Keeping concrete moist and at proper temperatures, beginning soon after it is placed, is one of the most important steps in making concrete that is dense and watertight.

COLD WEATHER CONSTRUCTION

Concrete can be made during cold weather just as well as at any other time, provided certain precautions are taken to insure proper curing.

In early winter, when freezing temperatures occur only at night, it is necessary merely to protect concrete from freezing after it is placed. As the weather grows colder and freezing temperatures prevail, the mixing water and aggregates are heated and the work protected.

Heating Water

Water is commonly heated in a large kettle, oil drum, tank or similar container supported over a fire, but can also be heated by discharging live steam into it. Regardless of the method employed in heating, it is best to take care that the temperature of the water is never greater than 150 degrees Fahrenheit when it comes in contact with the cement in the mixture; otherwise a too quick or flash set may take place. However, boiling water may be added to the aggregates before the cement is included. When this is done, the aggregates cool the water so that danger of a flash set is eliminated.

When concrete work is done in cold weather, water and other ingredients are heated so that concrete will have a temperature of 70° or more when placed in the forms.

An improvised heater is used here to warm aggregates and make sure that they are free from frost and ice.

Heating Aggregates

Several methods of heating sand and other aggregates are commonly used. The materials may be banked over a metal barrel laid on its side, a section of smoke-stack or some other improvised heater, and a fire kindled inside. A satisfactory heater for small jobs can be made by building a fire-box of concrete masonry units with a sheet-iron cover on which the aggregates are piled.

Sand and coarse aggregate should be heated separately to prevent them from becoming mixed. Frequent turning will result in uniform heating and thaw out all frost and ice. When steam is available, sand can be heated by placing a perforated 1-in. pipe into the pile and blowing steam through it. A tarpaulin cover over the sand will reduce the loss of heat. Cement should not be heated.

The temperature of aggregates when placed in the mixer should not exceed 140 degrees Fahrenheit.

Mixing and Placing Concrete

Make the concrete as stiff as possible and yet obtain a mix that can be readily placed and finished. Place immediately after mixing to prevent loss of heat. Remove frost, snow or ice from the forms before the concrete is placed.

If the ground on which concrete is to be placed is frozen, it should be thawed out before placing the concrete. If possible, have excavating done before the ground is frozen, covering the excavated areas with straw or other suitable coverings to protect the earth from freezing.

Heat hastens the hardening of concrete; cold retards it. When concrete is placed in the forms it is best that it have a temperature of not less than 70 degrees nor more than 100 degrees Fahrenheit. In cold weather the concrete should be maintained at a temperature of 50 degrees or higher for at least five days after placing.

Use of Admixtures

Specifications usually prohibit the use of salts, chemicals or other foreign materials in the mix to lower the freezing point of the concrete. Admixtures intended to quicken the hardening of the concrete are permitted only when used in quantities which will not be injurious.

Tests made on concrete jobs and in laboratories show that, within certain limits*, small amounts of calcium chloride or calcium oxychloride may be used in portland cement mixtures to hasten hardening. The best results are obtained with 2 to 4 per cent of calcium chloride or 7 to 10 per cent of calcium oxychloride by weight of the cement. If greater amounts are used, loss of strength results.

These compounds should never be used as a substitute for heating water and aggregates and furnishing proper protection and heat to the new concrete, but only as a means of increasing the rate of hardening.

The calcium chloride crystals are dissolved in the mixing water before adding it to other materials in the mixer. Most contractors make up a solution of known concentration, adding the desired amount to each batch. Thus, if it is desired to use 2 lb. of calcium chloride per sack of cement, a solution containing 1 lb. per qt. can be made, 2 qt. of the solution being added to the mixture for each sack of cement in the batch. It is important to remember that this solution is to be regarded as part of the mixing water. Calcium oxychloride does not dissolve readily; hence it should be mixed thoroughly with the dry materials before water is added.

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*There is evidence to show that calcium chloride and similar compounds do not react in the same manner with all brands of portland cement. Trial batches of the brand of cement and the brand of accelerator proposed to be used should be made up and rate of hardening at the specified temperature noted before proceeding with their use in important work.

Tarpaulins are used to protect freshly placed concrete during cold weather.

Protecting Concrete

As soon as the concrete is placed it is protected to retain the heat. Concrete walks, floors, pavements and other horizontal surfaces can be protected by covering with heavy paper and then with hay or straw 10 to 12 in. deep.

Outside walls can be protected by coverings of canvas or straw or by building enclosures around them and heating the interior with oil or coke stoves (the latter are commonly known as salamanders), or some other form of stove which will provide considerable heat without smoke. Salamanders and other stoves should not be placed near enough to fresh concrete to cause it to dry out. Keeping the concrete moist is especially important while heat is being applied, since winter air when heated has a severe drying effect.

Removing Forms

Too early removal of forms is to be guarded against when concreting in cold weather. It is recommended that forms remain in place until the concrete has attained sufficient strength to sustain its own weight in addition to any other load that may be placed upon it during construction.

Frozen concrete is frequently mistaken for properly hardened concrete because it may have the same "ring" when struck with a hammer. A reliable test is to apply heat or hot water to the surface. If frozen, the concrete will soften on thawing.

CYCLOPEAN CONCRETE

When large field stones or cobblestones are imbedded in concrete for massive structures, such as foundations, dams, piers and retaining walls, the product is called cyclopean concrete. The practicability of its use depends largely on the labor involved. Under farm conditions, where labor is available and the disposal of rock and boulders is a problem, it often effects a considerable saving. The stones must be sound and clean and each one completely surrounded by concrete. The large stones should not lie near each other or to an exposed surface.

LIGHT WEIGHT CONCRETE

By using aggregates of light weight, the weight of concrete may be reduced considerably. Light weight concrete is desirable for roof slabs, partitions, floor fills, fireproofing, masonry units and other purposes. Cinders are often used as aggregate in concrete floor fills and in masonry units on account of their light weight. Light weight aggregates made from burnt clays are now available commercially in many localities. Mineralized sawdust or shavings have been used in some cases. Where these materials are to be used in concrete that is to carry load, tests should be made to determine the combination of materials necessary to produce the required strength.

A wall of cinder concrete masonry units. Concrete made with cinder aggregate weighs considerably less than ordinary concrete and has somewhat higher insulating value.

Patented methods of aerating concrete are in use to some extent. For this process finely divided chemicals which generate gases are added to cement paste or mortar, causing it to expand so that, upon hardening, it is full of air spaces.

Concrete having weight as low as 50 lb. per cu. ft. may be made by aerating. Burnt-clay aggregate concrete weighs about 100 lb., cinder concrete about 120 lb., and slag concrete about 130 lb. per cu. ft. Ordinary concrete weighs about 145 lb. per cu. ft.

GUNITE

Within recent years there has been developed a method by means of which mortar can be applied with a gun. This product is called gunite and consists of sand and cement of various proportions, mixed dry, placed in the cement-gun dry, and ejected through a rubber hose by pneumatic pressure; the addition of water takes place at the nozzle. The force of impact expels superfluous moisture and air, and part of the sand (referred to as rebound), thus solidifying the mass and, if properly applied, producing a mass of considerable density and strength.

This product lends itself to placing of concrete in difficult locations and in plastering and repair work.

QUESTIONS

1. What factors must be considered in securing a watertight concrete?
2. How does the water-cement ratio affect the watertightness of the cement paste?
3. Why is the complete incorporation of the aggregates in the cement paste essential to watertightness?
4. What effect does heating the ingredients have upon the rate of hardening?
5. How can light weight concrete be secured?

CHAPTER VII

Coloring and Special Finishes

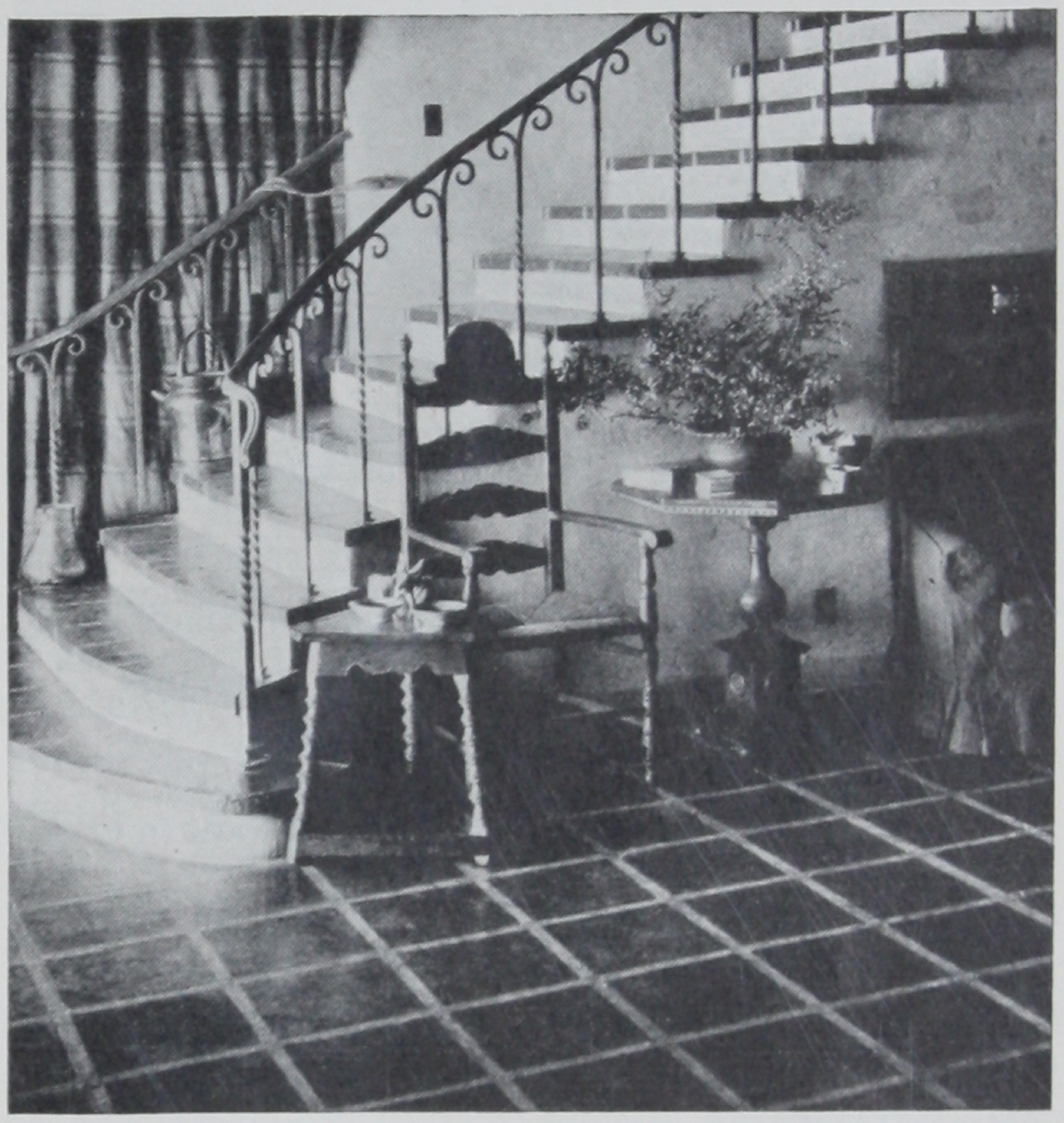
IN the earlier years of concrete construction, attempts were made to duplicate with it effects obtained with other materials more commonly used.

Continued usage has, however, brought to light the almost unlimited possibilities inherently its own. In this manual it will be possible to mention only a few of these and some of the more general considerations.

Variations in the effects of concrete construction can be obtained by different colors, textures and shapes. Color can be secured by the use of pigments in the cement paste, or by selected aggregates, or by both. Texture variations are obtained by special forms, subsequent surface treatments or by coatings such as washes or stuccos. Variations in shape result from the forms used.

COLORED CONCRETE

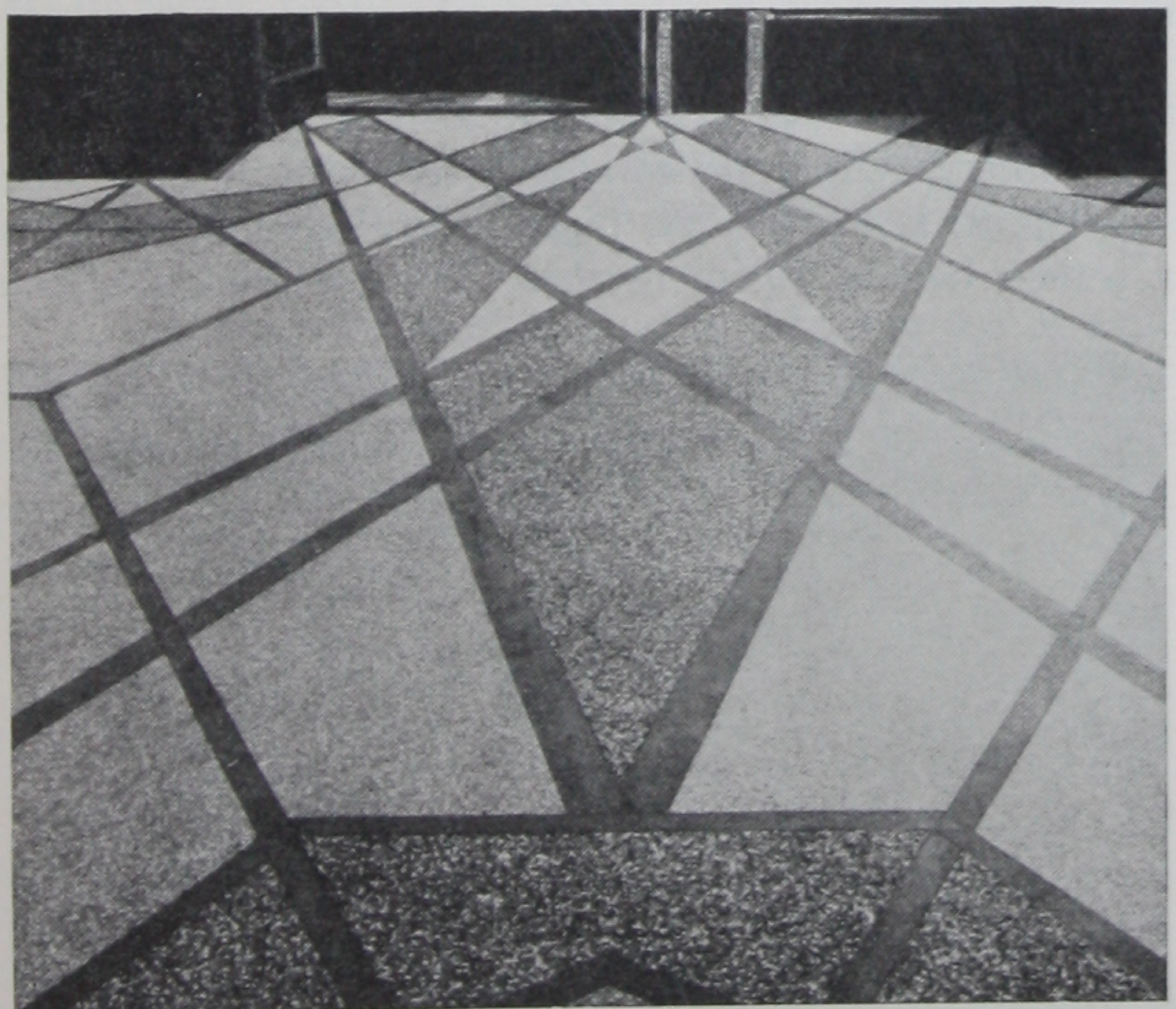
The following recommendations for producing colored concrete are based on tests both in the field and the laboratory and, if carefully observed, should result in thoroughly satisfactory work.



Colorful concrete floor tile helps make this entrance hall attractive.

Color Pigments

A color pigment suitable for use in concrete must fulfill the following requirements: (1) it must be durable under exposure to sunlight and weather; (2) it must produce intense color; (3) it must be of such composition that it will not react chemically with the cement to the detriment of either cement or color.



This colored concrete sidewalk, laid in a modernistic pattern, was built by a California merchant to attract business to his store.

The foregoing requirements are best fulfilled with mineral oxide pigments. Other pigments, such as organic dyes, have a tendency to fade and may reduce the strength of concrete. There are two satisfactory kinds of mineral oxides available: (1) natural oxides that come direct from the mines, and (2) manufactured pigments which are prepared especially for concrete work.

Ordinarily, natural mineral pigments cost less per pound than manufactured pigments and may be used where dull colors are satisfactory. Where bright colors are desired, manufactured pigments produce best results. To obtain a given intensity of color, more of the natural pigment is required than of manufactured pigment. It frequently happens that a smaller amount of higher-priced, manufactured pigment actually produces the desired results at a lower cost than the cheaper natural pigment.

The following recommendations will serve as a guide

This picture illustrates the proper consistency for a colored concrete floor topping mix; 5 gal. of water per sack of cement was used.

in determining proper pigments to use for colors listed:

Buff, Yellow or Red—Iron Oxide Pigments.
Green—Chromium Oxide Pigments.
Blue—Cobalt Blue or Ultramarine Blue*.
Brown—Iron Oxide or Iron and Manganese Oxide Pigments.
Gray, Slate and Black—Iron Oxide or Manganese Dioxide Pigments†.

The color which is produced in concrete is determined primarily by the proportion of pigment to cement and not by the proportion of pigment to cubic feet of mortar or concrete. Because of this, modern color specifications give the weight of color pigment to be used per sack of cement.

It has been found that pigments may be safely used in amounts up to 10 per cent of the weight of the cement—that is, 9 pounds of color pigment per sack (94 pounds) of cement. These limits may be exceeded with some pigments and under certain conditions. In such cases the manufacturers' directions should be followed.

The aggregates used in colored concrete should be as near the color of the mortar as possible. If such aggregates are not available, light colored, semi-transparent aggregates will give best results.

With high grade pigments, the amount recommended as a maximum—10 per cent of the weight of the cement—will usually produce deep shades of color. Lighter shades are obtained by using less pigment, and variations of colors or shades are obtained by mixing two or more pigments.

When pastel shades are desired, it is necessary to use white cement or a mixture of white cement and gray cement. In any case, cleaner and brighter colors can be obtained with white cement. It is preferable to use white cement as a means of obtaining strong colors rather than to use excessive amounts of pigments.

Variation in the composition of concrete materials as well as in the color pigments makes color formulas only approximate. For this reason it is suggested that after selecting the primary color desired the exact shade be determined by preparing a number of small mortar panels with the same materials and proportions as are intended for the finished job. The sample mortar panels should be 6 or 8 in. by 12 in. and about 1 in. thick. The proportions used for the different panels are carefully recorded so that when the correct shade is determined the exact proportion for that shade can be used on the job. Samples are stored away for four or five days under curing conditions the same as those on the job. Then they are dried and wiped off with a rag dipped in equal parts of paraffin oil and benzine, to bring out the color, and then inspected.

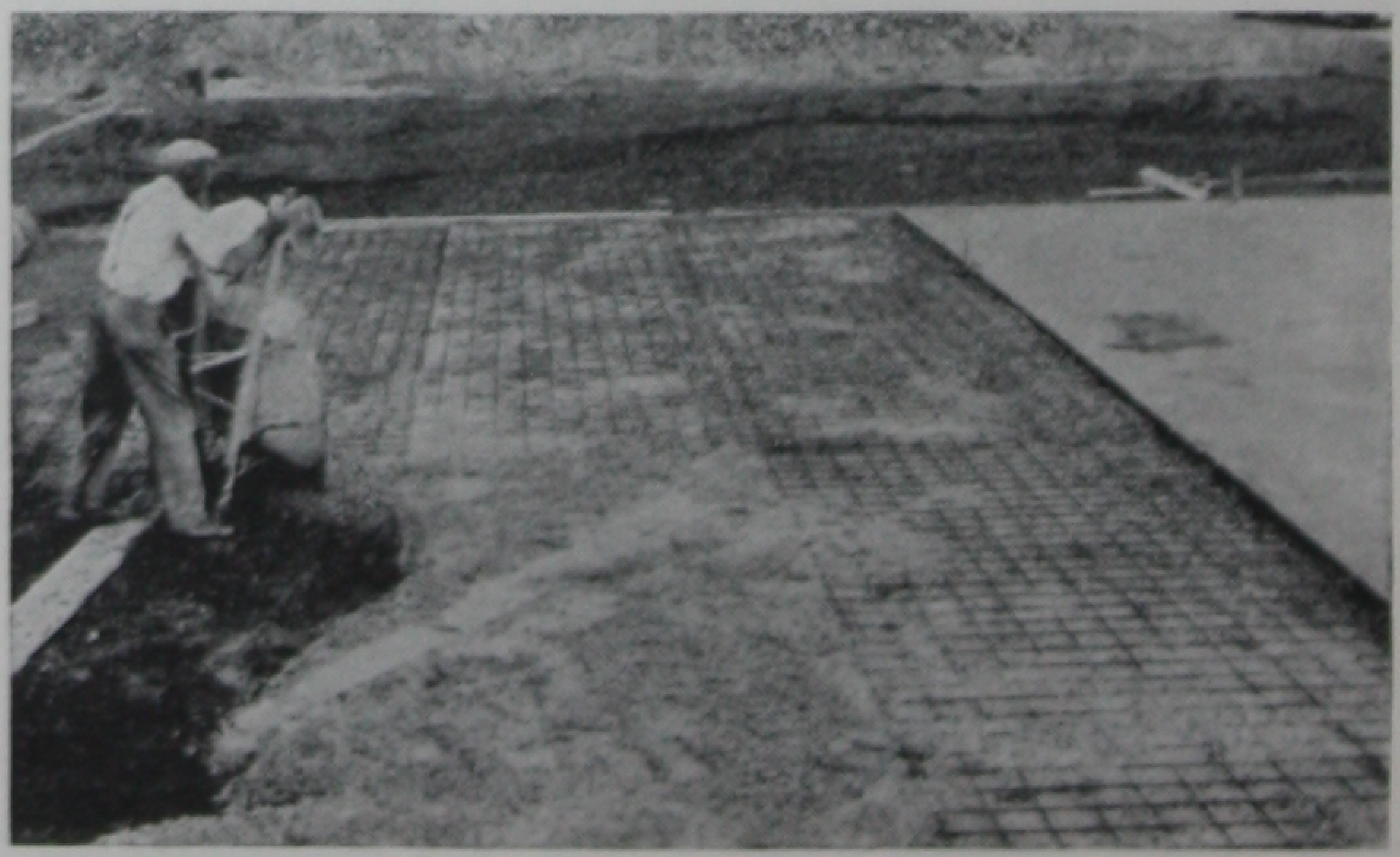
Mineral pigments vary considerably in coloring values. Most architects and builders depend upon the reputation of the manufacturer of pigments for assurance that the quality of the material is satisfactory for concrete work. In general, the finer a pigment is ground the greater is its coloring ability and the less the amount required.

Mixing Colored Concrete

In producing high quality colored concrete, the pigment and cement are mixed together before they are delivered on the job. Thorough mixing, which is hard to accomplish on the job, is essential for uniform color in the finished work. Color pigments do not penetrate the particles of cement, as do dyes in coloring cloth. Instead, the pigment forms a coating around the particles.

Where factory-prepared colored portland cement is available, it is often economical to use.

Another method of mixing, especially suitable for small jobs, is to pass the pigment and cement through a screen having ⅛-in. meshes. The correct quantities



Placing the base for two-course monolithic color work. Reinforcement is placed on top of the base course as shown.

*The only blue that can be absolutely guaranteed is Cobalt Blue. Ultramarine Blue should not be used unless manufacturer will assume responsibility for color.

†Use other types of black only when the manufacturer will absolutely guarantee reliability of color. For grays and slates, smaller quantities of pigment are used than for black.

of pigment and cement for a 1-sack batch are first measured out separately. The cement and pigment are then mixed thoroughly, passing the materials through the screen as many times as necessary to obtain uniform color.

An attractive sign post of concrete.

It is sometimes necessary to use a concrete mixer for mixing pigment and cement. In this case the mixer must be dry and free from loose particles of hardened cement or mortar.

It is necessary to measure all materials accurately, particularly where the work requires several batches. Even a slight variation in the amounts of any of the materials, particularly the pigment and water, is likely to cause noticeable variation in color.

For most colored concrete work, a mixture containing not more than 5 gal. of water per sack of cement is recommended when aggregates are dry. The mixture of colored concrete is made as stiff as possible without sacrificing workability. It should require light tamping or rolling to get it to settle into place. In determining the correct consistency for colored concrete, the slump test, described on page 24, will be useful. It will also be helpful in maintaining uniform consistency in all batches. Colored concrete toppings should have a slump of not more than 2 to 4 in.

The recommended trial proportion for colored concrete is 1 sack of cement, 1 cu. ft. of sand and 1¾ cu. ft. of clean, hard, pea gravel or crushed stone or slag ranging from ⅛ to ¼ in. in size and containing no soft, flat or elongated particles. Not more than 3 per cent of the fine aggregate should pass the 100-mesh screen and not more than 15 per cent should pass the 50-mesh screen.

A 1-2 mix for the colored concrete using coarse sand will give satisfactory results in protected floors and surfaces that will not receive heavy usage, provided the sand is well graded with not more than 3 per cent passing the 100-mesh screen, not more than 15 per cent passing the 50-mesh screen, and not more than 5 per cent retained on a ¼-in. screen.

When mixing materials on the job, the colored cement is mixed with the sand or other fine aggregate to be used in the concrete. With a 1-1-1¾ trial mix, for example, 1 sack of colored cement and 1 cu. ft. of sand are first thoroughly mixed dry. Then 1¾ cu. ft. of coarse aggregate is added and the materials thoroughly mixed again until uniform color is obtained, this being done before water is added. Thorough mixing after water is added also is essential.

Placing Colored Concrete

Colored concrete may be placed by any one of three recommended methods—two-course monolithic, regular two-course or the one-course method.

Two-Course Monolithic Method—This method, in which the colored topping is placed before the base course hardens, is used when the colored concrete can be placed and finished immediately as in driveways, tennis courts, walks and pavements. The concrete for the base is mixed and placed as in ordinary work.

Concrete topping should not be applied until the base course has stiffened somewhat and all excess water has evaporated or has been removed with a broom, belt, float or by other means. Brooming, for example, removes water, scum and laitance and produces a rough surface providing a good bond for the colored topping.

Regular Two-Course Method—This method is best suited to floor work and similar construction where it is not desirable to place the topping until other construction work has been completed. When this method is to be used, it is best to leave the surface of the base course fairly rough to secure a good bond with the topping. Prior to placing the topping, this surface is thoroughly cleaned and dampened. A thin coat of cement grout is broomed onto the surface a short distance ahead of the topping as the latter is placed.

One-Course Method—Where the full thickness of concrete is placed, as in the one-course method, placing is much the same as in ordinary work. However, it is seldom economical to place the full thickness with colored concrete except for thin slabs or when only tints rather than deep colors are desired.

Placing Colored Topping—In either the two-course monolithic or regular two-course method, placing of the topping is essentially the same. The minimum thickness of the topping usually is ½ in. for light wear or moderate exposure; 1 in., for heavy wear or severe exposure. As soon as the topping is placed it is leveled off with a strikeboard and given a wood-float finish.

A soft brush is being used here to give a slightly gritty, non-slippery texture to a concrete tennis court.

Finishing Colored Topping

Where a smoother finish than that imparted by the wood float is desired, the surface is left undisturbed for 30 to 45 minutes depending upon temperature and weather conditions. When all surface water has disappeared and there is no visible sheen, the concrete is finished lightly with a steel trowel. It is important to trowel only in one direction to get uniform color.

Too much emphasis cannot be placed on the necessity for extreme care in the use of the steel trowel. An expert can, with a minimum amount of steel troweling, develop a beautiful, smooth surface which will be free from dusting or checking and which will have good wearing quality. On the other hand, excessive troweling draws fine material to the surface which greatly reduces its wearing quality. A good point to keep in mind is that the fewer strokes required to produce a smooth surface, the better will be the job. Additional information on finishing is given on page 31.

Curing

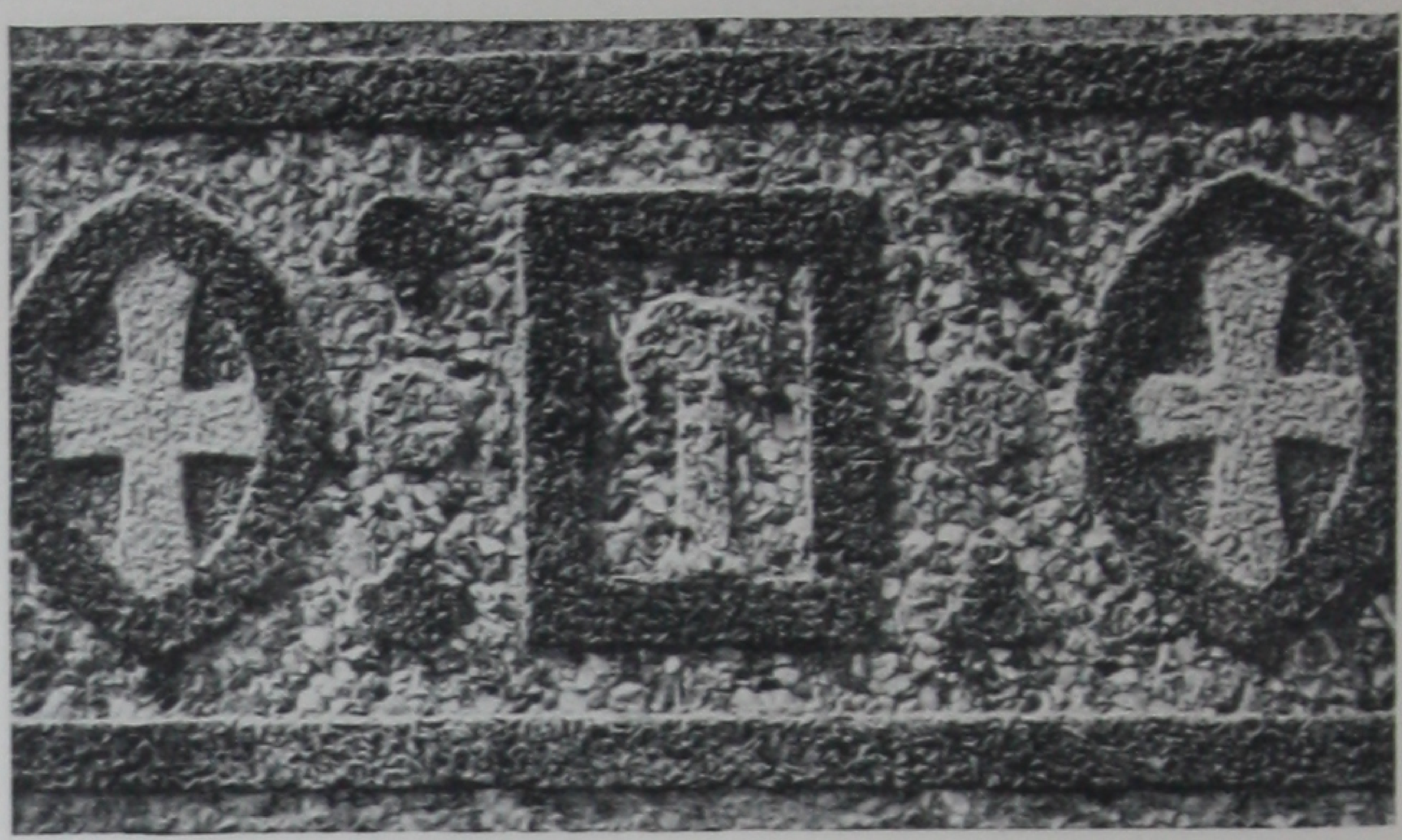
The proper curing of colored concrete is important, for it develops strength, watertightness and resistance to wear. Recommended methods of curing are discussed on page 31.

Dusting

Dusting or wearing of concrete surfaces usually indicates a defective finish due, in most cases, to improper finishing and curing. If fresh concrete is troweled too much, fine material is drawn to the top resulting in a surface which lacks durability. It is never good practice to sprinkle dry cement or a mixture of cement and fine aggregate on concrete to take up surface water. Such fine materials form a layer on the surface that is likely to dust or hair check when the concrete hardens.

If a concrete surface is not allowed to cure properly, it does not become hard and it lacks durability. Proper curing and finishing are the best preventive measures for defective finishes and subsequent dusting.

Checkers becomes an outdoor sport—when there's a concrete court like this.



Carefully selected colored aggregates, exposed by scrubbing, were used in obtaining this decorative concrete surface.

Efflorescence

Efflorescence, sometimes called blooming, is a deposit on the surface and in the pores of masonry building materials such as brick, clay, tile, limestone, marble, terra cotta and concrete. It usually results from the passage of water out of the material carrying soluble substances dissolved from some constituent of the material. When this water reaches the surface and evaporates, the substances are deposited.

This deposit, being whitish in color, is particularly noticeable and objectionable on colored concrete surfaces. Obviously, if concrete is made watertight, the likelihood of efflorescence is reduced to a minimum. Proper proportioning of the mixture, use of not more than 5 gal. of water per sack of cement, thorough mixing, and proper placing, finishing and curing will produce watertight colored concrete.

Where efflorescence occurs, it may be dissolved by a dilute solution of muriatic acid (1 part of concentrated acid to 10 parts of water). In using this treatment the surface of the concrete is wet before applying the acid and is thoroughly washed after the acid treatment.

The length of time required for the acid solution to dissolve efflorescence will depend upon the amount of the latter. In most cases, the acid can be washed off within three or four minutes. It is best not to leave the acid solution on longer than four minutes, for it may etch the colored concrete. If some deposit remains after the first application, a second can be made. The acid solution should be brushed on smoothly, using the least amount possible for each application.

Efflorescence also can be removed with a solution of equal parts of paraffin oil and benzine rubbed vigorously into the surface when the concrete is dry. This treatment also improves the wearing qualities of the surface by filling the pores and bringing out the color more uniformly. It is frequently applied to concrete surfaces for these reasons only.

Cleaning Colored Concrete

Colored concrete surfaces may be cleaned and made more impervious by washing with liquid soap. When this treatment is used the soap should be applied and allowed to stand over night, being washed off thoroughly the next morning.

The application of ordinary floor wax once a month after the concrete is dry and clean will produce deep colors, improve the wearing surface and make it easy to keep clean. After the first two or three waxings, two applications a year will be sufficient unless the surface is to be subjected to unusually severe wear.

SPECIAL SURFACE FINISHES

Concrete may be handled to produce a great variety of surface finishes. Some finishes are partly arranged for when the materials are selected, others are imparted by the forms, and others are produced entirely after the concrete has hardened.

Concrete to be given special surface finishes must be made with well graded aggregates which are attractive when exposed or cut. Such concrete also must be fairly stiff when placed to prevent segregation—that is, to make certain that aggregate will be uniformly distributed throughout the mass.

Use of Selected Aggregates

Among the most attractive finishes are those which are pre-arranged when mixing the materials. Aggregates are selected for their color as well as for their ability to take polish. Among the aggregates commonly used are white sand, marble chips, granite screenings, crushed feldspar, mica-spar, crushed slag, garnet sand and similar colored rock materials.

The mixtures are prepared and placed in the usual way and the surface finish is secured by washing off the surface film of cement exposing the aggregates and revealing their color.

When forms are removed within a few hours, the surface film of cement usually can be washed off by spraying with water under pressure or by scrubbing with a stiff brush and water. When the concrete has become too hard to yield to this treatment, an acid wash of one part muriatic acid to four or five parts of water is used. The wash is applied with a brush scrubbing lightly until the film of cement has been removed. The surface is thoroughly washed with clean water immediately afterward to remove all traces of the acid.

A wide variety of colors and textures may be secured by exposing the aggregates. Different combinations of the materials produce different effects. A mix of yellow and white marble chips or of gray granite screenings and black crushed slag with a little mica-spar are examples of possible variations.

In producing a granolithic surface, a mix containing approximately 1 part portland cement, 1½ parts of fine aggregate and 2½ parts of coarse aggregate made up of pebbles, crushed granite, or other stone which may be desirable and suitable, is used for the facing or topping. For floors and similar work, the construction is practically the same as for two-course monolithic or two-course work as discussed under *Placing Colored Concrete*, page 41, with the granolithic mixture being used as a topping.

For walls and other vertical work, the granolithic surface is made by placing about 1 in. of facing material against the face form as the backing of ordinary concrete is placed, care being taken to see that the facing is placed in a manner that will insure its bonding with the backing. The level of the facing material usually is kept a few inches higher than the backing. When special metal or wooden molds are used to hold the facing concrete while placing the backing, the mold is removed before initial setting occurs.

Finishes Imparted by Forms

Surface finishes imparted to the concrete by the forms may be smooth, rough, paneled, or fashioned in almost any manner desired. If wooden forms are used, they are constructed of tongue-and-grooved material, evenly matched and tightly placed. It is best to construct forms in sections of such dimensions and shapes as will make their removal easy without undue hammering and without prying against the face of the concrete. Small openings in the forms may be pointed flush with stiff clay or plaster of paris to prevent leakage or the formation of fins.

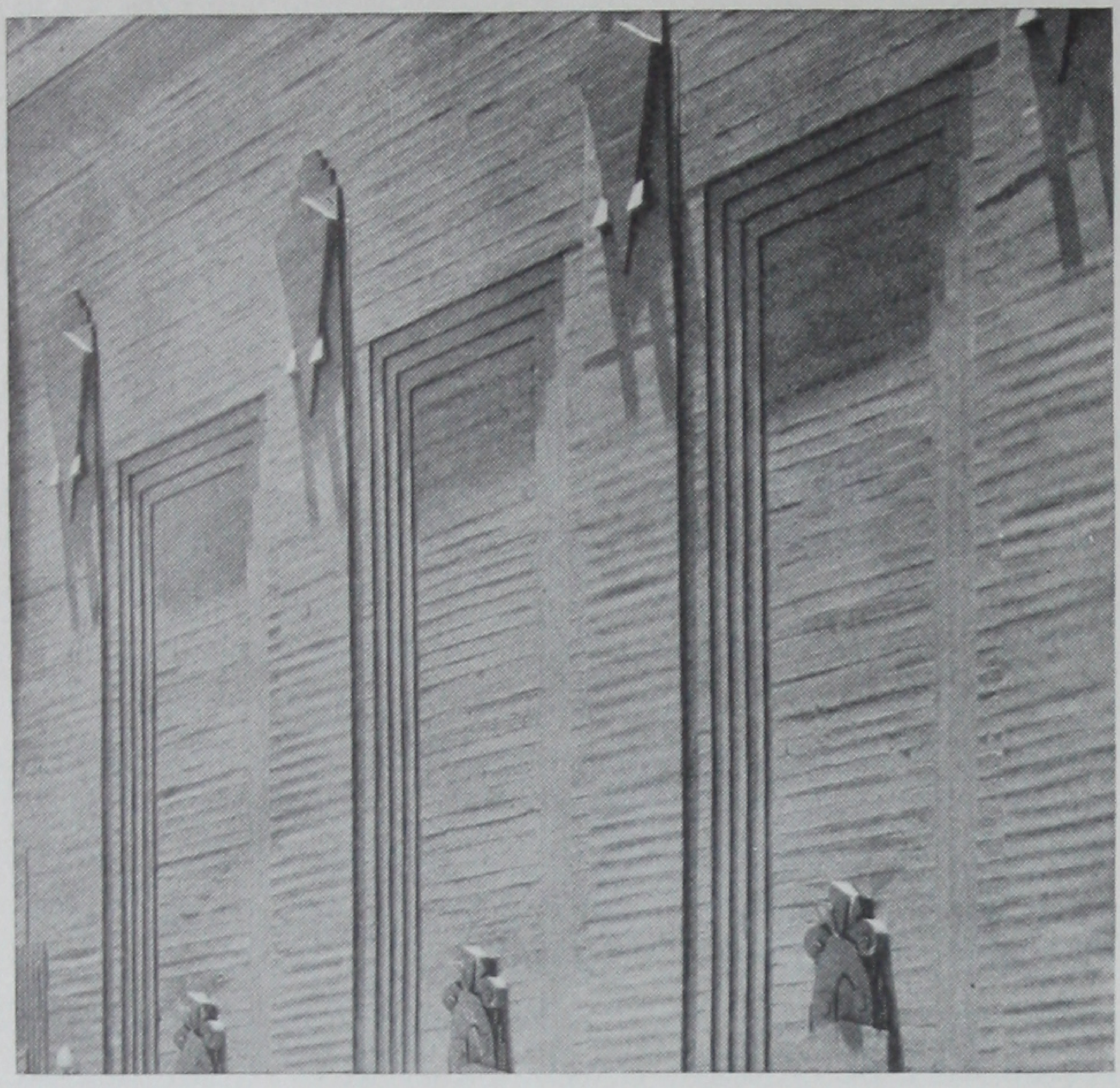
The use of screws will often help in the removal of forms and will make possible a minimum amount of prying with the least possible damage to the surface. Considerable skill is required to set form panels in place, plumb and properly aligned, and fasten them so there will be no movement under the pressure of the concrete. Any movement between panels will produce unsightly ridges. Despite first class workmanship such ridges sometimes occur. It is well to build form panels of such sizes and shapes that any form lines will conform to the design.

Face forms are removed as soon as practicable, in order to permit effective repair work. Any fins or other objectionable projections are removed at this time. Voids or damaged places are cleaned, filled with a mixture of the same composition as that used in the surfacing, and covered to permit proper curing. A wooden spatula or float is used to finish such patched areas. The use of a steel trowel is not recommended for this purpose.

Rubbed Finish

Decorative treatments which may be produced after the concrete has hardened include finishes developed by rubbing, scrubbing, sand blasting, tooling, bush hammering, sand floating and cement washes.

In producing the "rubbed finish," forms are removed as soon as possible. The surface is then wet thoroughly



A wide variety of surface finishes can be given to concrete by the forms. On this wall, form marks have been softened somewhat by rubbing with abrasive stones.

and scrubbed with No. 20 abrasive stones while the concrete is still "green." The lather that works up on the surface is removed by brushing and washing. Small voids in the surface are filled with a mortar composed of 1 part portland cement and 2 parts of the same kind of sand as was used in the facing concrete. This mortar is worked into the face with the abrasive stones so that no appreciable thickness of coating remains. A coating of any appreciable thickness is to be avoided as it may peel off and crack.

Several months after the first rubbing and when the concrete has attained a considerable degree of hardness, the surfaces again are rubbed down. This time No. 24 abrasive stones and water are used. Again a lather will be worked up which is removed with a clean wet brush. While this amount of rubbing produces an attractive surface, it usually does not remove form marks.

Scrubbed Finish

To produce a "scrubbed" or "brush" finish, the forms are removed while the concrete is still quite "green" and the surface is scrubbed with wire brushes, water being used freely. The scrubbing is continued until the surface film of mortar is removed and the aggregate is uniformly exposed. The surface is then rinsed with water. If parts of the surface have become too hard to scrub in equal relief, diluted muriatic acid (1 part acid to 4 or 5 parts water) may be used. Remove all acid with clean water after scrubbing, to prevent further action.

The best time to begin scrubbing is learned by experience. If begun too soon, unsightly voids may be made by scrubbing out pieces of aggregate. If the scrubbing is not started soon enough, the concrete will be so hard that the brush will not remove the surface mortar.

It is almost impossible to obtain sharp corners in scrubbed work and for this reason fillets of rounded moldings usually are placed in the forms so as to leave no sharp corners.

Sand-Blast Finish

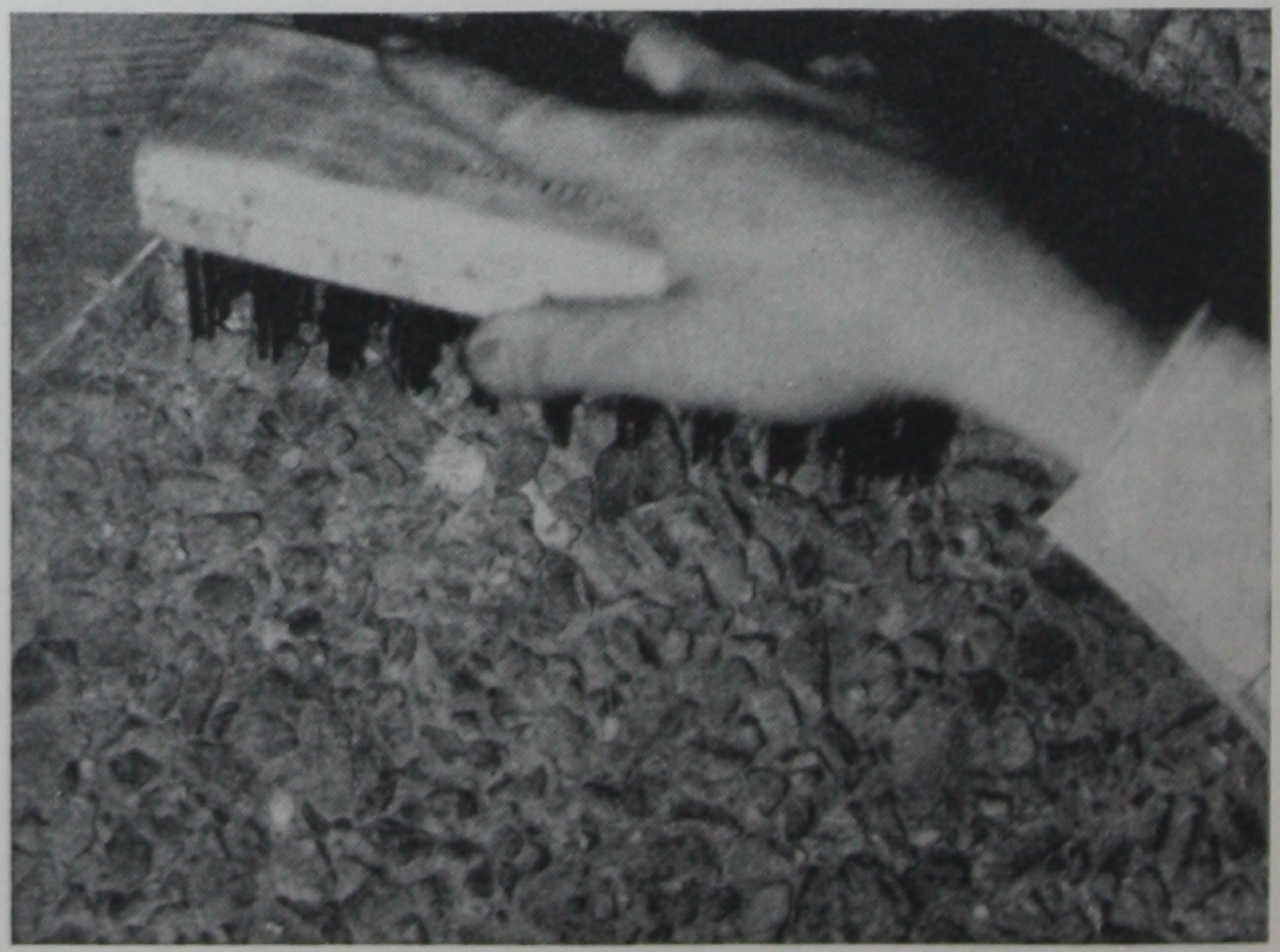
Another method used to expose the aggregate is sand blasting the surface with hard sand until the desired degree of relief is obtained. A concrete surface thus treated must have become fairly hard. The equipment necessary for sand blasting is large and, therefore, seldom is used on small jobs because of a comparatively high cost.

Tooled and Bush-Hammered Finishes

The surface resulting from tooling or bush hammering is very attractive because this method not only exposes the aggregate but cuts it as well. The cut aggregate, when properly selected for texture and grading, gives sparkle to the surface and life to the finish.

The concrete, of course, must be thoroughly hard before tooling or bush hammering is begun. The bull point used in tooling may be operated either mechanically by an air or electric hammer or by hitting with a hand hammer. The texture obtained by tooling is used to best advantage on large work.

"Bush hammered" or "dressed" finishes are often used for ornamental entrances and similar decorative work. Bush hammering and tooling present difficulties at corners, because it is almost impossible, at such places, to prevent chipping out of pieces of concrete, leaving ragged, unsightly corners. To prevent this diffi-

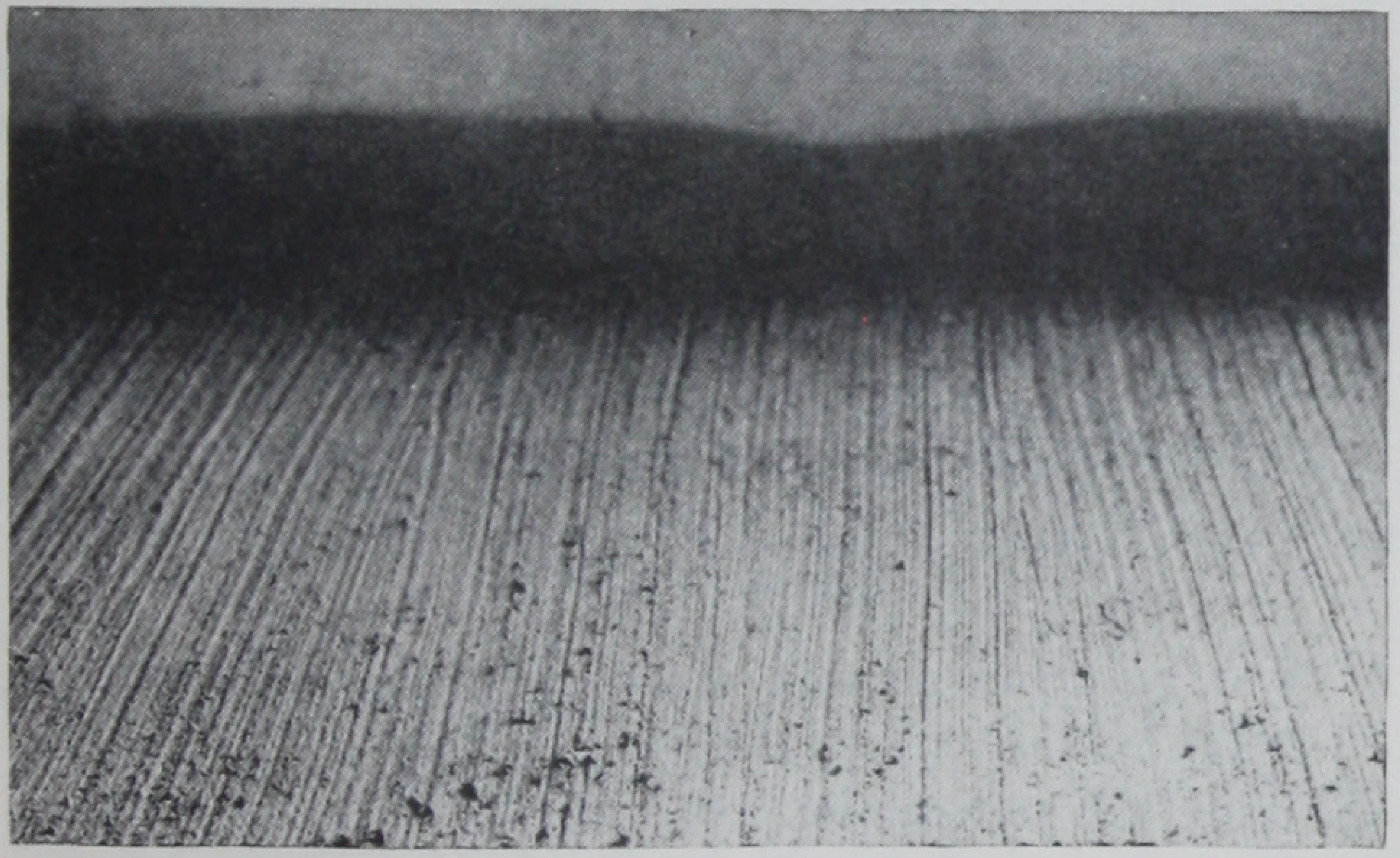


Exposing aggregates by scrubbing with a stiff wire brush and water. If the concrete has become too hard, it may be necessary to scrub with a solution of muriatic acid and water.

culty, corners can be given a "rubbed finish" and the hammering stopped at a sufficient distance from the corners to leave a smooth marginal draft line of a width that will be in scale with the panel that is being treated. This often leads to laying out the panels in such sizes as will be best fitted for treatment by hammering.

Sand-Floated Finish or Cement Wash

The surface is first cleaned thoroughly and voids are filled. The surface is then wet thoroughly and a cement wash or mortar is rubbed into the surface with a wood float operated with a uniform circular motion. Practically any color, ranging from white or cream to the gray color of cement, can be applied by varying the proportions of white cement with gray cement, and light or dark sand.



Broom finishing produces a slip-proof surface suitable for tennis courts, barn floors, etc.

The consistency of cement wash or mortar should be that of a very stiff oil paint. After this grout has been rubbed into the surface, a clean dry brush is used to brush the surface in the direction of the board marks. Excess grout is removed and only the thinnest coat required to cover the surface is left in place. A thick coat will eventually craze and peel off.

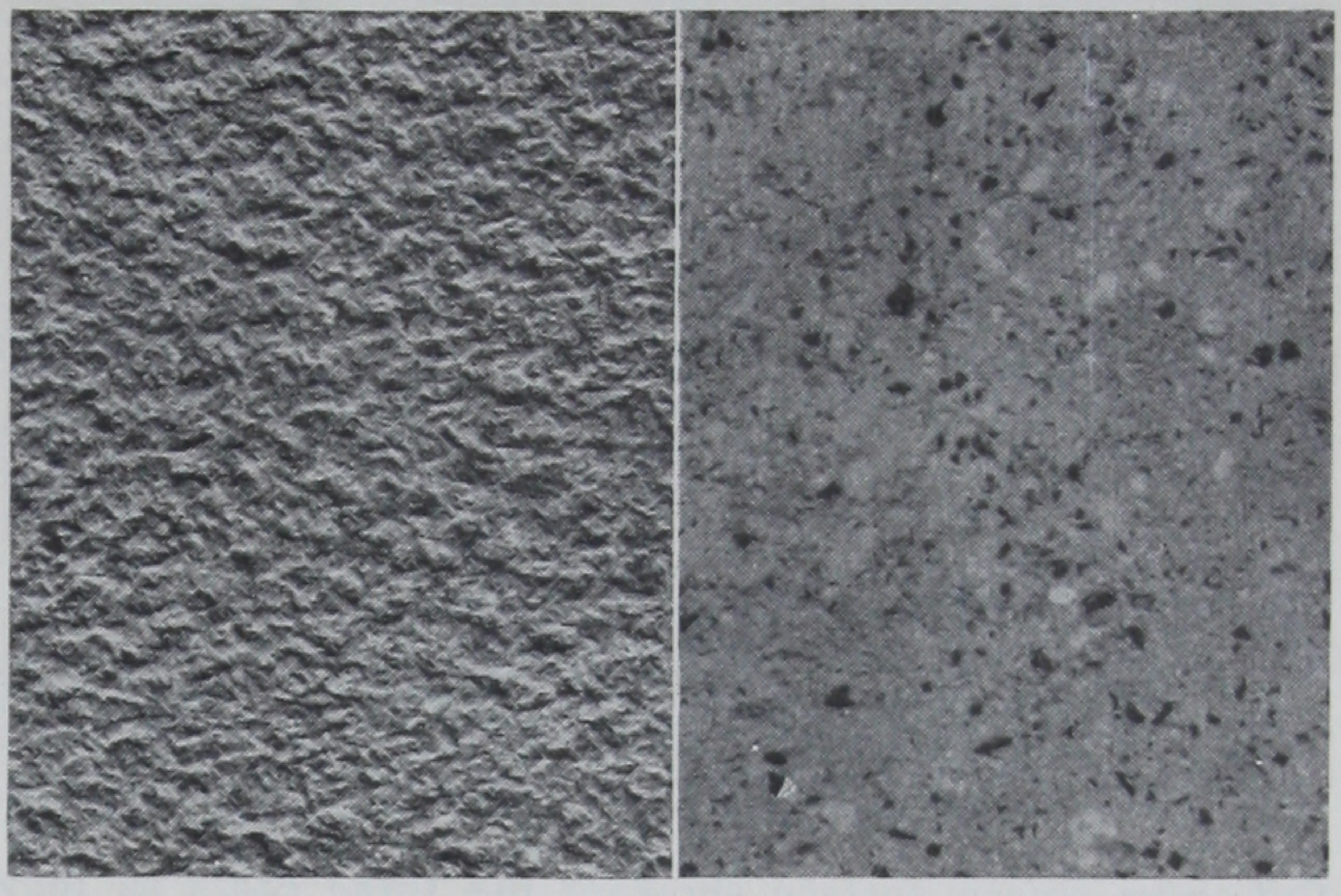
A surface produced in much the same manner, except that the grout is rubbed in with an abrasive stone, will prove more enduring and of better appearance.

With any method of producing sand-floated or cement-wash finish, it is necessary to keep the surface damp for at least two or three days after finishing to provide proper curing.

PLASTER AND STUCCO

Many pleasing effects can be obtained with portland cement plaster. Here again, the limitations are largely determined by the user.

Good judgment in the use of colors and surface treatments, as well as certain precautions in preparing and placing the material, are necessary for satisfactory work. A few typical finishes are shown on page 46.



Two attractive wall finishes produced by bush-hammering (left) and sand blasting (right) the hardened concrete.

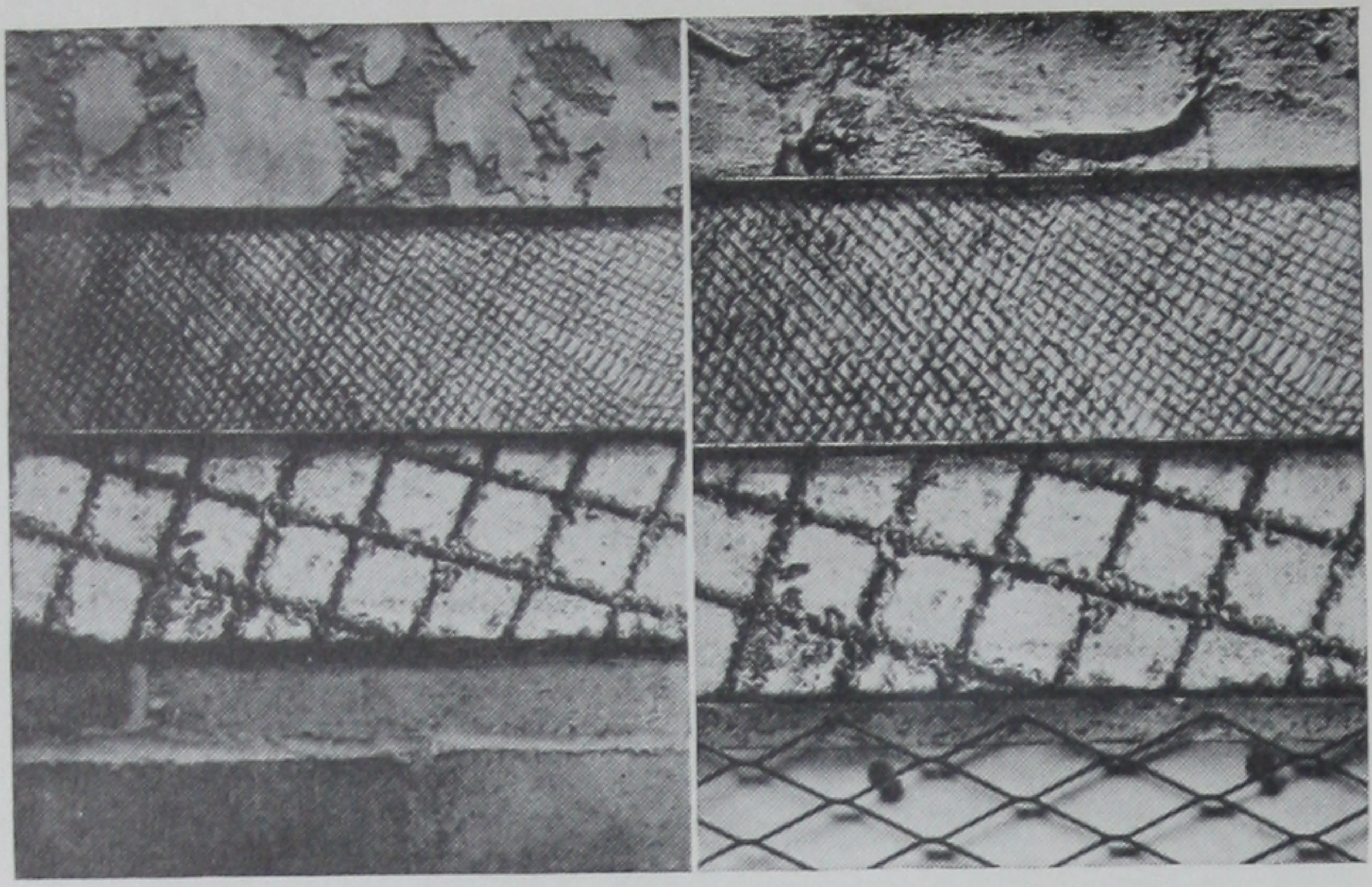
The following fundamental rules must be considered in the production of good stucco:

1. Use a good rigid base which will not shrink, warp, bend or deteriorate with time.
2. Use proper proportions and carefully selected sand and aggregates of correct fineness.
3. If an absorbent base, such as hollow tile, concrete block or brick is used, it must be sprinkled with water just short of the point of saturation before applying fresh stucco.
4. All stucco coats—base or scratch coat, second or brown coat, third or finish coat—must be thoroughly cured and then allowed to dry out.
5. Each stucco coat must be sprinkled with water before the next coat is applied, and the finish coat must be kept evenly moist by sprinkling. In hot weather, the work must be shielded from the direct rays of the sun and protected at all times from the wind. *The importance of these precautions cannot be over-estimated.*

Design

Whenever the design of the structure permits, an overhanging roof or similar projection is recommended to afford protection to the stucco. It is well for the architect to prevent concentration of water flow getting at the stucco at all, so as to avoid staining of the finish. Stuccoed copings, cornices and other exposed horizontal surfaces should shed water quickly, and whenever departure from the vertical is necessary (at water tables, belt courses, and the like) the greatest possible slope should be obtained.

Stucco should not be run to the ground, but should have a water table or belt course high enough above ground to avoid splashing of mud and dirt upon the finished surface. The backing should be of hard tile, brick, stone, or concrete, providing good mechanical bond for the stucco, and must be thoroughly cleaned before plastering.



Cut-away stucco surface showing the three coats as they are applied over masonry and frame walls.

Flashing

Suitable flashing should be provided over all door and window openings and wherever projecting wood trim occurs. Wall copings, cornices, rails, chimney caps, etc., should be built of concrete, stone, terra cotta, or metal with ample overhanging drip groove or lip, and watertight joints.

If copings are set in blocks with mortar joints, continuous flashing should extend across the wall below the coping and project beyond and form an inconspicuous lip over the upper edge of the stucco—or the joints should be pointed with an elastic pointing compound. Continuous flashing with similar projecting lip should be provided under brick sills. This flashing should be so installed as to insure absolute protection against interior leakage.

Cornices should be provided with flashing over the top, or the joints pointed with an elastic pointing compound. Sills should project well from the face of the stucco and be provided with drip grooves or flashings as described above for brick sills. Sills should also be provided with stools or jamb seats to insure wash of water over the face and not over the ends.

Special attention should be given to the design of gutters and downspouts at returns of porch roofs where overflow would result in discoloration and cracking. A 2-in. strip should be provided at the intersection of walls and sloping roofs and flashing extended up and over it, the stucco being brought down to the top of the strip.

Preparation of Original Surface

All roof gutters should be fixed and downspout hangers and all other fixed supports should be put in place before plastering is done, to avoid breaks in the stucco.

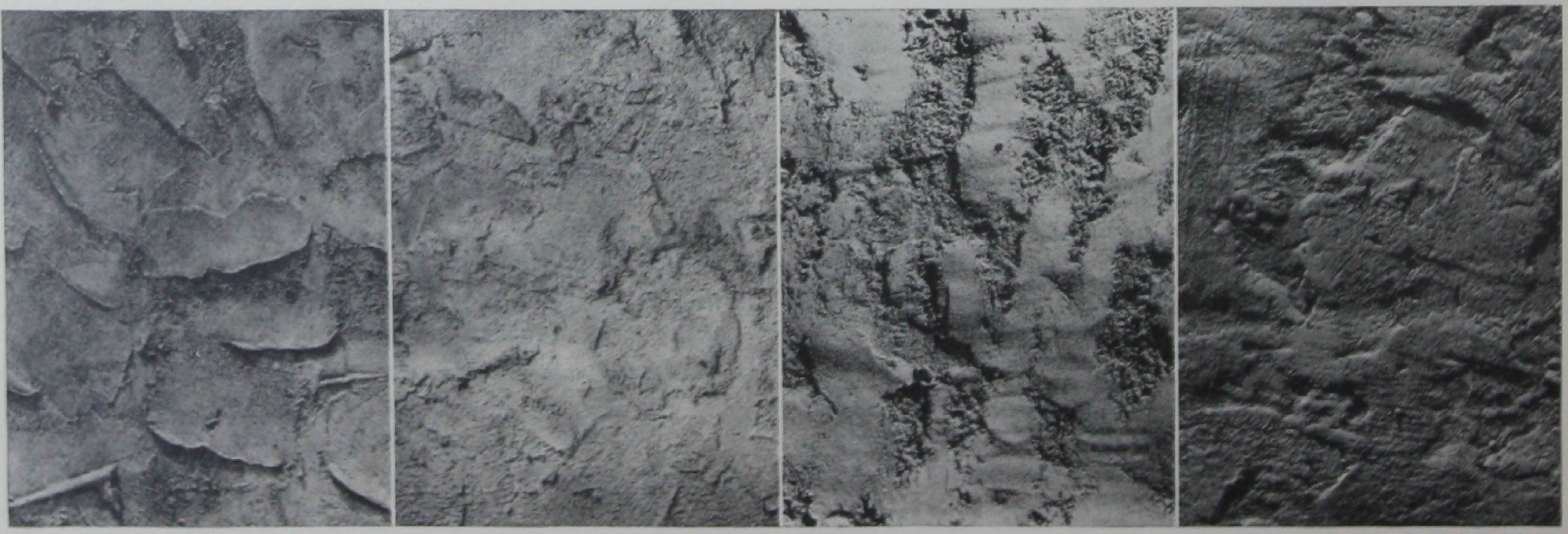
All trim should be placed in such manner that it will show its proper projection in relation to the finished stucco surface, particularly in overcoating.

USE OF PAINTS AND STAINS

Concrete surfaces are also adapted to treatments with other materials. Ceiling beams, when cast with rough lumber forms which leave the impression of the grain, take on a very realistic appearance when given a coat of stain. Modern decoration calls for color prominence. Paint applied directly to concrete walls opens a field bounded only by the imagination of the decorator.

QUESTIONS

1. For portland cement stucco or watertight mortar, what mix is recommended?
2. How can mortar be colored?
3. How can attractive surfaces be obtained in concrete work?
4. What effect has sand blasting on concrete which has not fully hardened? Why is it done?
5. What are the requirements of color pigments for concrete work?
6. What precautions should be observed in placing colored concrete?
7. How can forms be used to produce special finishes?



Portland cement stucco makes possible a wide variety of attractive, durable wall finishes. Here are four of the many textures which may be produced.

CHAPTER VIII

Concrete Masonry Construction

CONCRETE masonry construction is a term commonly used to denote an assembly of precast concrete units in building construction. Practically every community is within trucking distance of a plant where these building units are made or a material yard where they are carried in stock. In localities where it is not possible to obtain concrete block, building tile, or brick, builders will find it possible to manufacture their own concrete building units. Information as to where suitable machines or molds can be bought, as well as instructions on manufacturing methods, can be obtained upon request from the Portland Cement Association.

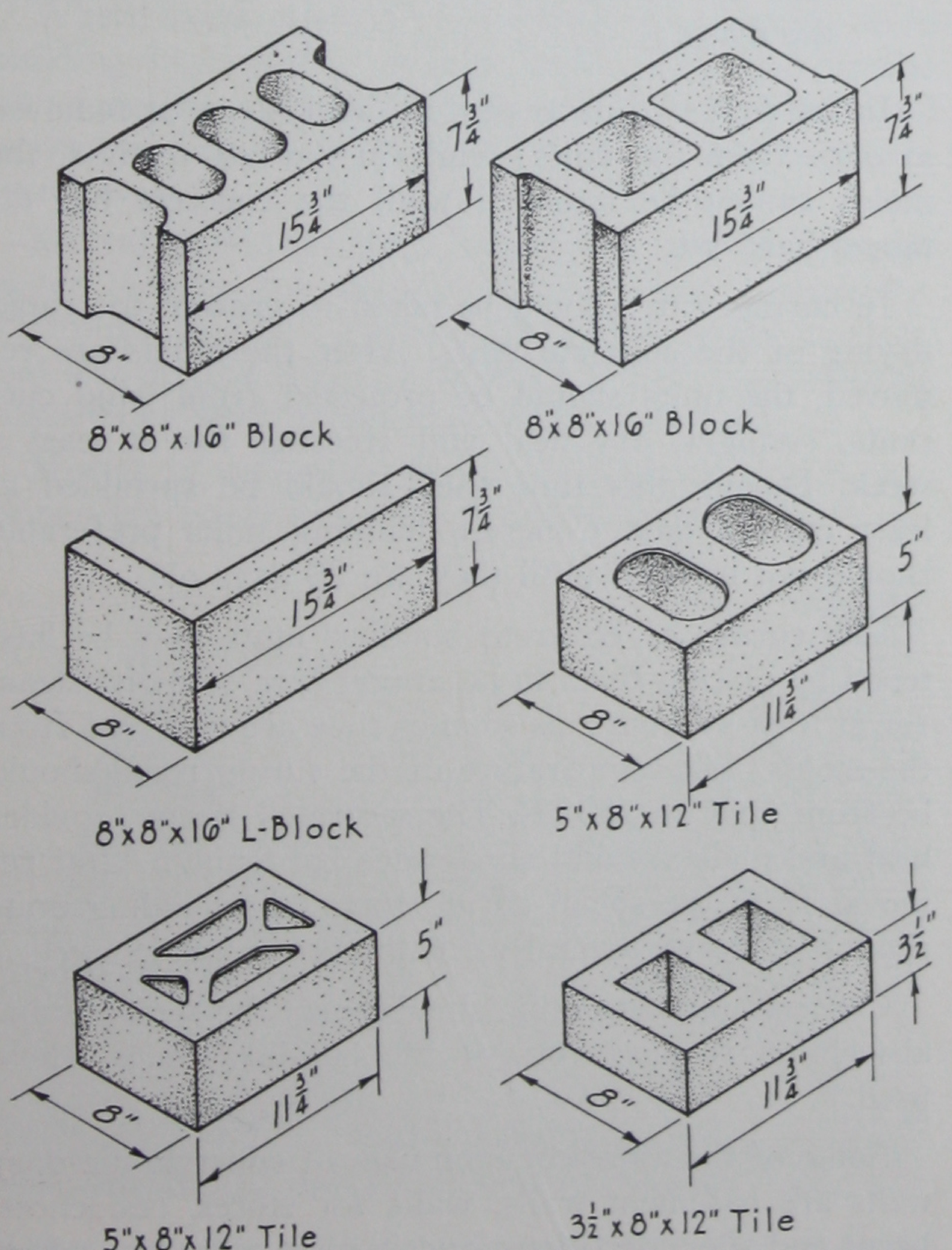
BLOCK

Concrete block are made in several sizes and shapes. The standard 8 by 8 by 16-in. size is probably the most widely used. Laid up in single thickness, it produces a wall 8 in. thick and courses 8 in. high. The 8-in. height is equal to 3 courses of brick. Block are also made regularly in the 10 and 12-in. widths with 8-in. heights and 16-in. lengths for basement and heavy wall construction.

A block ordinarily spoken of as an 8 by 8 by 16-in. size usually measures 7¾ by 8 by 15¾ in., allowance being made for ¼-in. horizontal and vertical mortar joints. Half length block make it unnecessary to cut full length units on the job if a little care is observed in designing the building.

Buildings may easily be designed so that the width and length as well as distances between doors and windows are equal to a given number of full and half-length block. For example, a wall exactly 24 ft. long will take 18 full-length 16-in. block in each course; a wall 26 ft. long will require 19 full-length and one half-length block.

Most concrete block are made with voids or air spaces. These lower the conductivity of heat, thereby making a warmer wall and also effect a saving in materials.



Some representative types of concrete building units.

BUILDING TILE

Concrete building tile are smaller in size and have somewhat thinner wall sections than block, a standard size being 5 by 8 by 12 in. One such tile is equivalent in wall volume to 6 common brick. The height of 5 in. is equal to two courses of brick. Walls 8 or 12 in. thick are obtained by a single thickness of tile, according to

Lower walls of this barn are of concrete masonry resting on a solid concrete foundation.

the way it is turned in the wall. The air spaces in concrete tile occupy from 50 to 60 per cent of their volumes. Manufacturers regularly furnish half-length units.

In addition to half-length units, most manufacturers and dealers handling block and tile furnish corner block, joist block, door and window jamb block, sills, lintels, and other specials. These enable the mason to lay up the wall more rapidly and to turn out a neater job.

BRICK

Concrete brick are used when smaller units are desired. These are usually made of the customary 2¼ by 4 by 8-in. size.

SURFACE FINISHES

Most products plants carry in stock, rough, flat-faced block or tile for stucco covering and in addition one or two types of face block. For basement walls below grade the plain unsurfaced block is extensively used. For work above grade, the owner may select faced units or he may use the plain unsurfaced block, depending on the class of work. For all farm buildings except the residence the plain unsurfaced block when carefully laid presents a wall of satisfactory appearance. For dwellings, it is customary to use faced units either with or without a portland cement paint coating, or plain block covered with portland cement stucco.

Concrete masonry provides an ideal backing for portland cement stucco. The surfaces of concrete block and tile are sufficiently rough to provide a strong mechanical key or bond for the stucco.

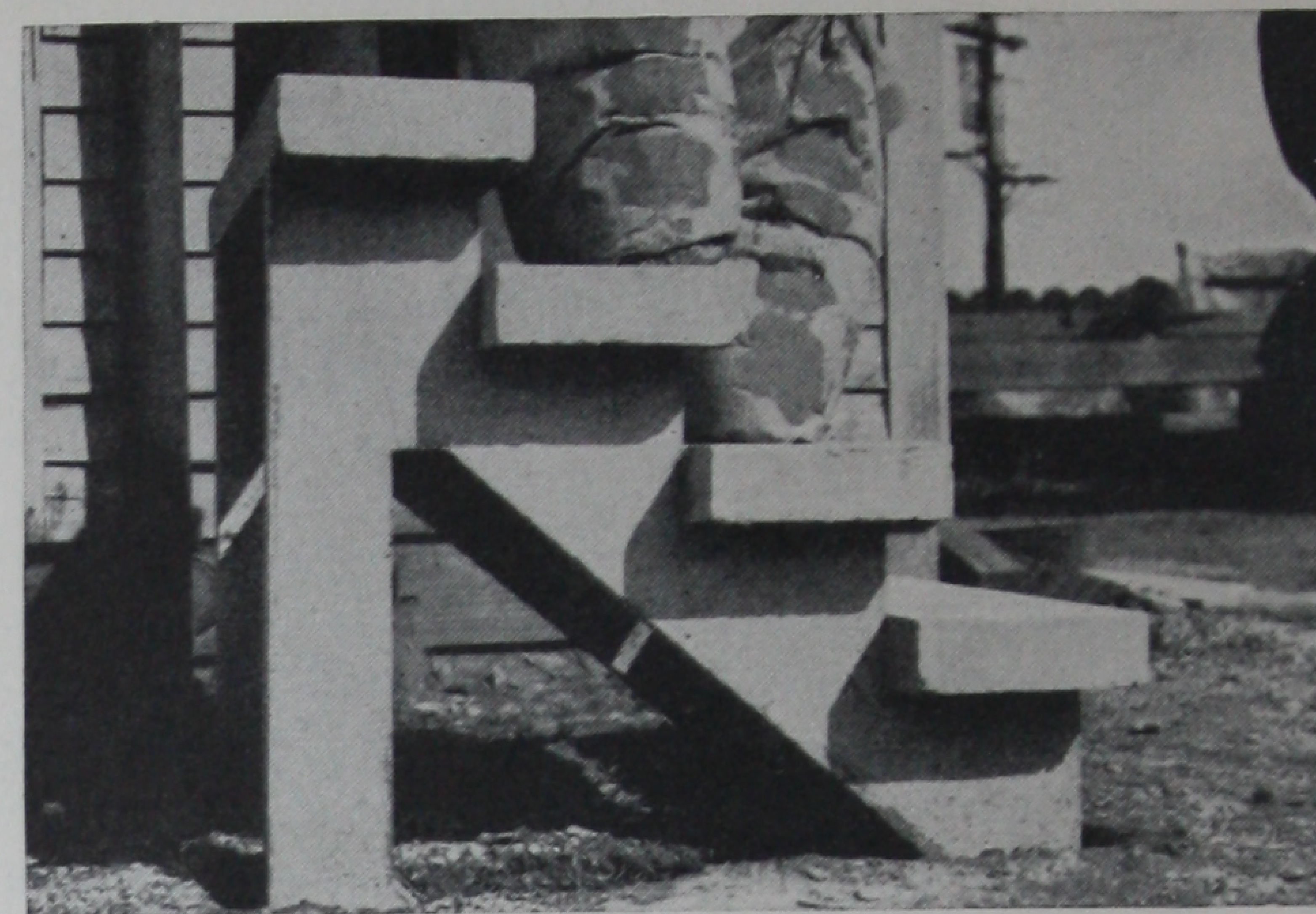
MANUFACTURING PROBLEMS

The materials used in the manufacture of concrete building units are portland cement and fine and coarse aggregates. In general, materials suitable for first class concrete work are also suitable for making concrete building units, except that the maximum size of aggregate rarely exceeds about ½ in. and should always be less than half the thinnest wall or web section. For special surfaces and finishes, various kinds and types of aggregates are used similar to those described in the preceding chapter under *Special Surface Finishes.*

Four methods commonly used in the manufacture of standard concrete building units:

1. *Tamp Process:* The materials are mixed to a damp consistency and are then tamped in the molds by hand or by machine tampers. Care should be taken not to get the mix too dry.

2. *Vibrated Concrete:* By this process, a fairly stiff mix is made dense and compact by vibration.



Many small articles can be precast and moved to the desired location. These are precast concrete steps.

3. *Pressure Process:* A somewhat wetter mix is used than in the tamp process. The mixed concrete is placed in the molds and compacted by pressure applied either by mechanical levers or by a hydraulic piston.

4. *Cast Process:* In this process the consistency of the mix is such that the concrete will flow readily. The mix is deposited in the molds, and puddled or vibrated to remove air and to compact the mass.

In the first two processes, the molds can be removed at once from the units; while in the last method, the molds cannot be removed until the concrete has attained hard set.

In curing, care should be taken to prevent too rapid drying of the concrete units. After the molds are removed, the units should be protected from wind currents, sunlight, dry heat and freezing for at least a week. During this time they should be sprinkled at least once a day. Concrete building units preferably should not be used until they are 28 days old.

The curing of concrete building units may be hastened by placing them in an atmosphere of moist steam for at least 48 hours, as soon as they are removed from the molds. The temperature of the curing room should be from 100° to 130° F. The saturated steam provides heat and moisture and accelerates hardening. After removal from the steam curing room, the building units should be stored several weeks before using.

Concrete building units should meet the strength and absorption requirements of the building codes where used.

Some of the more common uses of concrete masonry units are basement walls, walls for stores, residences, barns and silos, partitions, and in most any place where a tight, durable, fireproof wall or partition is desired.

CONCRETE ASHLAR

Concrete *ashlar* is an economical, attractive concrete masonry construction. The concrete masonry units may be laid in regular courses in which case it is *coursed* ashlar, or a number of different sized units may be laid in a random manner called *random* ashlar. A combination of coursed and random ashlar may be used making possible a large number of attractive wall patterns. The concrete masonry units may be painted before laying or after the wall is built, using portland cement paint which is available in a wide range of colors.

MASONRY WALL CONSTRUCTION

Portland cement mortar is recommended for laying concrete block and building tile because of its great strength, density and ability to resist weathering. Cement mortar should be made with clean well-graded sand and clean water. Well slaked or commercially hydrated lime is usually added to make mortar more plastic or "fat." Commercially hydrated lime is carried in stock by most building dealers. Slaked lime is made by adding water to lump lime, which is also obtained from the dealer.

For ordinary work, a mortar composed of 1 part portland cement, 1 part lime and not more than 6 parts sand, all measured by volume, is considered satisfactory.

Where extra strength and density are desired, as in building block water storage tanks, silos and similar structures, a mortar consisting of one sack of portland cement to 3 cu. ft. of sand and 10 lb. of lime is recommended.

Mortar should be mixed thoroughly with just enough water to give the desired plasticity and workability. Thorough mixing improves the plasticity of mortars, and less mixing water is required to obtain a workable consistency when time of mixing is increased.

Mortar is commonly mixed by hand, although machines are sometimes used for this purpose. Tools required for hand mixing are hoe, shovel and mortar box. Cement and sand are mixed together dry. If hydrated lime is used it can be mixed in with the cement and sand. When lime putty (slaked lime) is to be used, the lump lime is dissolved in water to a creamy consistency and is then added to the previously mixed cement and sand. Mix only enough mortar at one time so that the entire batch can be used before it begins to harden. Mortar that has partly set up should not be used.

Homes and other buildings today are protected from flying sparks by fireproof cement-asbestos shingles or concrete roofing tile.

Concrete ashlar makes a pleasing interior wall with excellent acoustical properties.

Colored mortars can be produced by following the instructions given for coloring concrete.

The concave type of mortar joint is usually preferred for farm buildings. It is made by drawing a pointing tool along the joint after the mortar begins to stiffen. This operation compacts the mortar and produces a tight, water-excluding joint. Both vertical and horizontal joints are usually made from 1/4 to 3/8 in. thick. When the wall is to receive a portland cement stucco finish or is to be plastered, the mortar is struck off flush with the wall.

Two men generally work together in laying concrete block or concrete building tile. One man, called a helper, prepares mortar and brings it within easy reach of the other, who lays the block. The mortar is brought either in a hod which is carried on the shoulder or in a pail carried by hand. The hod is convenient when mortar is to be carried up a ladder. However, pails may be used and a rope and pulley arrangement fixed up to raise mortar to the scaffold. The mortar is dumped upon a mortar board or laying board, which is a platform about 3 ft. square constructed of boards.

Corner block are often set first and chalk lines stretched tightly between them to serve as a guide in building a straight wall. These lines should be of stout cord such as cotton. Binding twine is useless for this work. If the corner block are accurately placed and plumbed, the line kept taut, and the block laid to the line, the wall will be plumb and true.

Frames for doors and windows are set in proper position and built into the wall with special jamb block that abut against the frames. When floor levels are reached special "joist" block are set which have notches cut out for the joists. Another method is to use veneer block on the outside wall, filling in between joists with similar shorter block.

Plates or sills are attached to concrete masonry walls with bolts placed at intervals of 6 ft. apart or less through at least the top two courses. Anchorage is secured by slipping a large washer on the bolt and filling around the latter with concrete.

Concrete footings, placed below frost line and made wide enough to prevent settlement, support concrete masonry foundation walls.

CAST STONE

Cast stone is the term applied to building stone manufactured from concrete. By making the forms to the proper shape and using selected aggregates, almost any desired effect can be secured. Molds for cast stone may be constructed of metal, plaster-of-paris, wood or sand according to which seems the most desirable for the work.

The operation of casting concrete in sand is similar to that of casting iron. The pattern is made of wood the exact size required. It is then molded in sand exactly as is done in the casting of iron. A concrete mixture of very wet consistency is poured into the mold. Generally the casting is left in the sand for three or four days and after being taken from the sand is allowed to harden in the air before being finished.

Wood molds consist of side planks and end pieces resting on a pallet, and held together by clamps. In tamped work, the facing mixture, if one is used, is placed in the bottom of the mold, up to the front and part way up the ends, as desired, and then the backing mixture is added and tamped in place. The concrete is struck off smooth at the top, a layer of bedding sand added, and a plank placed on top of the sand and clamped in place. The entire mold and contents are turned over, so that the piece is right side up when the mold is removed. When the concrete has hardened sufficiently, the mold pieces are removed, and the cast stone left right side up on the plank.

In the wet cast method, a smooth concrete floor or table top is shellacked and oiled, and the form pieces erected thereon, with the necessary insert pieces and dividers. A concrete of rather wet (quaky) consistency is used, and the concrete stone is left in the molds until it has thoroughly hardened.

Walls of concrete building units can be quickly and easily laid by any competent mason.

Various metal molds are now made for different ornamental pieces and standard architectural units. These molds need only be cleaned and oiled, and can be used many times. When necessary, the individual pieces (such as lintels) may be reinforced.

Plaster is used quite extensively for making models and molds for ornamental cast stone. Skilled workmen can make a suitable plaster model from an architect's drawings. When a plaster mold is finished, it is shellacked and oiled, and a mold made over the model. The model is removed from the mold and the mold surface shellacked and oiled before the concrete is added. With plaster molds, the concrete mix may be of pouring consistency or may be quite dry and lightly but firmly tamped in the mold. Draw molds may be used when there is no undercut or when the undercut sections of the mold are made so that they will readily separate from the main part, and can be removed easily after the main part of the mold has been drawn. Draw molds must be smooth and trim, and tapered a little so they can be withdrawn without injuring the concrete. Plaster molds may be used several times.

Gelatin or glue molds should be used where there is much undercut, which would necessitate making a plaster mold in many pieces. In making a glue mold, the

A milk house of concrete masonry with concrete floor and cooling tank is a big aid to the dairy farmer in meeting sanitary milk regulations.

model is first covered with paper, and a thin layer of modeling clay added. This clay covering is greased and plaster added over it to form a shell with several holes or air vents. When the plaster mold is hard, it is removed, and the clay and paper cleaned from the model. The surfaces of the model and mold are shellacked and oiled, the model is placed in the mold, and the space between filled with hot glue. The air vents can be stopped with clay as the space is filled. When the glue is hard (requiring about 24 hours) the plaster mold is first removed and then the glue mold is cut into a few parts and removed from the model. Concrete of pouring consistency must be used with a glue mold because in it concrete cannot be tamped. A glue mold can be used about four times, after which the glue may be remelted and used again.

Sometimes various combinations of molds are used, such as wood strips in plaster molds, plaster inserts in wood molds. For difficult ornamental work, when much duplication is necessary, a glue mold is first made, then a glue model, and then several plaster molds from the glue model. When there is much undercut, the plaster mold is cut away from the concrete and discarded, no attempt being made to save the plaster for re-use.

Placing forms for casting floor slab over precast concrete joists. Floors of this type are fireproof and compare favorably in cost with frame construction. Any type of floor finish may be used over the concrete slab.

Cast stone is widely used for both exterior and interior ornamentation. Intricate and pleasing designs are easily obtained.

Molding sand should be a fine sand which will mold well when wet. The sand is often mixed with fine loam or plaster, and sometimes with an integral waterproofing powder. The sharp edges in the mold may be built up of wood inserts, as the sand edges may crumble. As sand tends to stick to concrete surfaces, it is always necessary to give this type of cast stone some surface treatment.

Although most cast stone is made of the same mix and material throughout, it is very easy to provide facing mixtures, especially in the tamped method.

Color effects may be produced by the use of mineral pigments as previously described.

QUESTIONS

1. For what types of construction are masonry units more suitable than monolithic construction?
2. What advantages are gained by making air spaces in a masonry wall?
3. What are the requirements of a good mortar?
4. What precautions should be observed in coloring mortar?

CHAPTER IX

Reinforced Concrete

REINFORCEMENT is the term used to describe the steel bars or small or large mesh metal placed in concrete to increase its tensile strength. Concrete is a material which is very strong in compression—that is, in bearing loads that are placed directly upon it; but it requires steel bars or other metal reinforcement in some structures to increase its resistance to stresses or forces that tend to bend or pull it apart. In a concrete lintel over a door or window opening or in a beam, for example, reinforcement is placed near the lower side, as that is the side which tends to pull apart when the lintel or beam is loaded.

On most construction work, sizes, location and spacing of reinforcement usually are determined in advance by experienced engineers, blueprints showing details of construction being furnished. Where it is necessary to determine the sizes and spacing of reinforcement, it is recommended that an engineer experienced in reinforced concrete design be consulted.

Reinforcement should be free from rust, scale or other coatings that will reduce the bond between the concrete and the steel. It is necessary to clean bars or metal reinforcement which do not meet this requirement. Bending or straightening reinforcement in a manner that will injure the material is to be guarded against. Heating of reinforcement likewise is not permitted. No. 18 annealed wire usually is used to tie reinforcement together where lapping and intersections occur.

Reinforcement should be accurately placed and secured, and be supported by concrete or metal chairs or spacers or metal hangers. Ordinarily, reinforcement is placed after all form work is built.

In general, it is recommended that all reinforcement be protected by at least a ¾-in. covering of concrete. In placing concrete, it is desirable to work the material around and under all reinforcement and embedded fixtures, working the concrete with suitable tools. Where conditions make spading difficult, or where reinforcement is closely spaced, batches of mortar containing the same proportion of cement to sand used in the concrete are first deposited in such locations. Then filling with the specified mix is carried on in such a manner that the concrete is plastic and places readily, with light tamping, around the reinforcement. Tapping the form with a rubber or wood mallet or any similar practical method may be used to make the concrete settle around and under reinforcement. Specifications usually limit the maximum size of aggregate to ¾ of the minimum spacing between reinforcing bars.

A good demonstration can be carried on in the school shop to illustrate the effectiveness of reinforcing as well as the proper location for it. Using the same molds and testing machine as have been previously suggested for

Reinforcement bars must be accurately placed. As a general rule, all reinforcement should be at least ¾ in. from the nearest concrete surface.

A system of concrete roof construction recently developed in Germany employs a thin shell of concrete, heavily reinforced.

demonstrating the effectiveness of the water-cement ratio, make several beams with the reinforcing bars located near the bottom of the beam, another group with the bars midway from top to bottom, and a third with the bars near the top. The reinforcing bars must extend the full length of the beam. For this purpose they can be located by first filling the mold to the height desired for the reinforcing and completing the filling after the bars are in position.

QUESTIONS

1. What is reinforced concrete?
2. When is reinforcement necessary?
3. Would you reinforce a fence post? A barn foundation? A sidewalk? A flat concrete roof?
4. Where should reinforcement be placed in a beam?
5. How can one insure getting concrete into all corners and around the reinforcement?
6. What materials are suitable for reinforcement? Why?

In reinforced concrete work, it is necessary to place concrete under and around all reinforcement to obtain a good bond between concrete and steel.

CHAPTER X

Projects and Problems

PRACTICAL application of the principles learned in the classroom should be obtained by making various articles of concrete. The selection of these will depend largely on the facilities at hand and the interest of the individuals in the class.

Simple projects, preferably small in size and requiring easily made forms should be undertaken first. Larger pieces may be used as supplementary home projects.

A few simple projects are included here. Many others are included in publications listed in the bibliography. Particular reference is made to:

Concrete Improvements Around the Home.
Permanent Farm Construction.

The student should be encouraged to be constantly on the lookout for other projects that will be valuable and interesting.

Laboratory directions are not given in complete detail. Any course should strive toward the developing of initiative and the student should be encouraged to plan his own procedure so he will be able to do a concrete job systematically when engaged in projects outside the shop.

The principles governing each step should be constantly referred to. From the selection of the aggregates to the curing of the product, not a single step can be safely slighted. Habits are being developed which may prove beneficial or detrimental later according to how they are handled here.

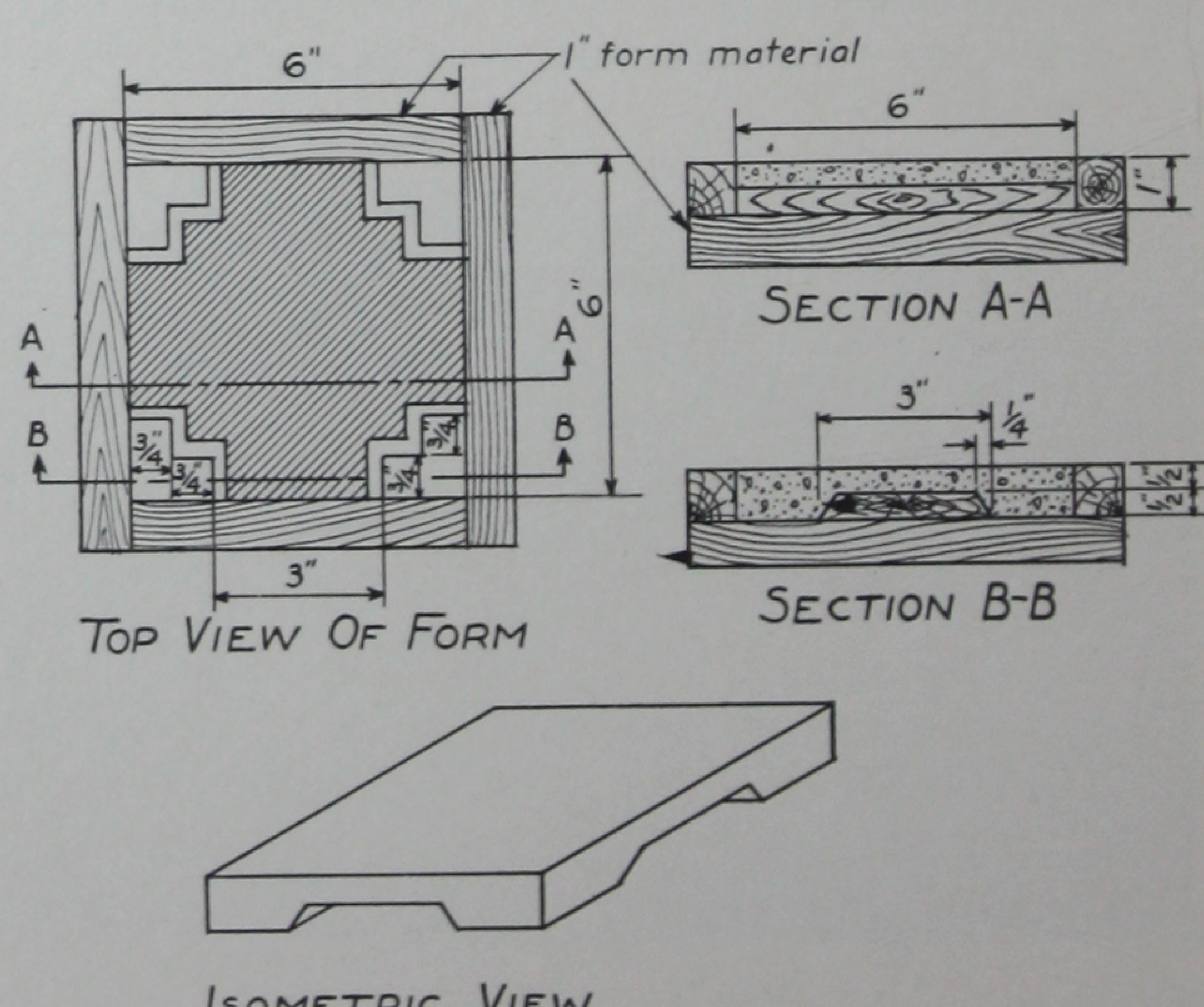
For the smaller exercises, the cement paste should be mixed first and the sand and pebbles, proportioned as recommended, added slowly until the correct degree of workability is obtained. The water-cement ratio in all of the exercises is given on the assumption that moist aggregates are to be used. If the aggregates are dry or wet, it will be necessary to alter the quantities accordingly (see Table I, page 18).

Tea Tile

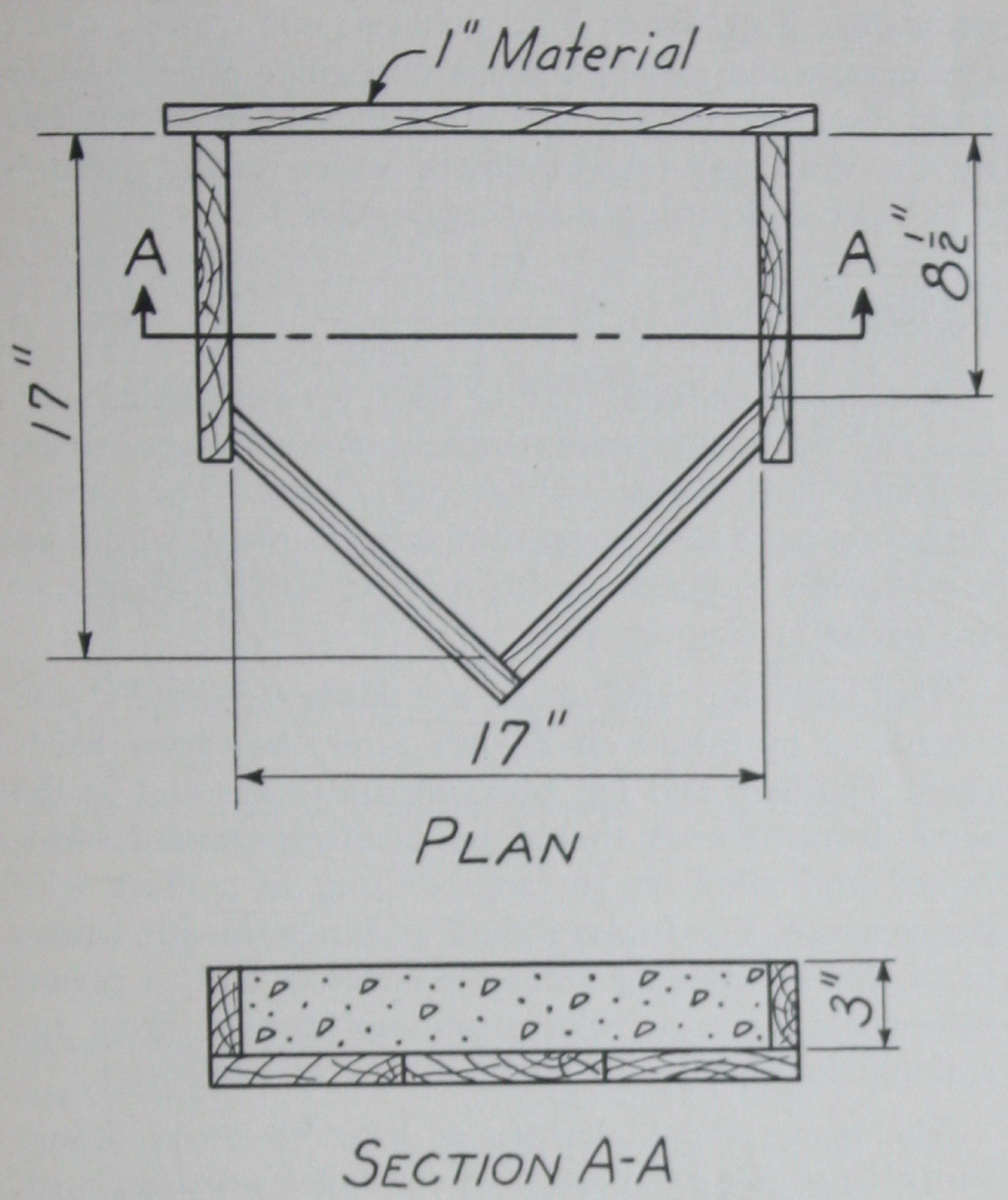
A tea tile is a useful article for the dining table, to hold the tea pot, coffee pot or other hot dishes. It also admits of wide variation in shape, color and design to meet varying abilities and imagination. It can be made square and simple or elaborate and decorated. Colorings as described in chapter VII can be used. By use of stencils and different colored mixtures, designs similar to that shown in the illustration can be produced.

In making the tea tile, assemble the form on the pallet, setting the bottom form or core inside the square frame. All surfaces coming in contact with the concrete should be shellacked to produce a smooth surface. When dry, these surfaces should be oiled.

Originality may be expressed in the design of a tea tile.



Forms for making a concrete tea tile.



A baseball home plate can easily be made using the forms shown here.

When the concrete has been placed, the top surface should be smoothed off with a trowel and the edges beveled. In removing the form, the outer frame and bottom board or pallet should be taken off first.

Care must be taken in removing the core so as not to injure the concrete.

A tile with a glass smooth top surface can be produced by setting the frame on a piece of glass and filling the lower part with mortar, pressing it down well. The core form is then placed so that it will be level with the surface of the frame, care being taken to fill the corners with mortar and to smooth them off neatly.

This method is employed when two colors are used in the top. One color of mortar is first placed in a stencil cut from ¼-in. wall board. After the stencil is removed, the form and the other color are placed as indicated above.

Materials and Equipment—One-half qt. of cement; ⅓ qt. water; approximately 1 qt. sand; oil; small mixing board; trowel; quart measure; form constructed according to sketch; wood or glass pallet, 8 in. square. (Note: sand only is used as aggregate in making the tea tile. The water-cement ratio indicated is approximately 4½ gal. to a sack of cement when moist aggregates are used.)

Baseball Home Plate

Another project which requires only simple forms and is easily finished is a baseball home plate. By placing it flush with the ground, players will not be injured when sliding into it. If desired, the other three bases can be made of concrete also.

In making the home plate shown in the drawing, the form should be assembled on a piece of oiled paper about 2 feet square, laid on a flat surface. If preferred, the home plate can be cast in place by digging a hole and placing the forms in the desired location. After the concrete has hardened, the forms may be removed and the dirt filled in around the base.

Materials and Equipment—One-fourth cu. ft. of cement (15.6 lb.); 4½ qt. water; ⅓ cu. ft. sand; 2/5 cu. ft. pebbles; oil; mixing board; shovel; wood float; a 1 by 4-in. board 72 in. long to be cut as indicated in the drawing; 7d box nails. (Approximate water-cement ratio 4½ gal. to sack using moist aggregates.)

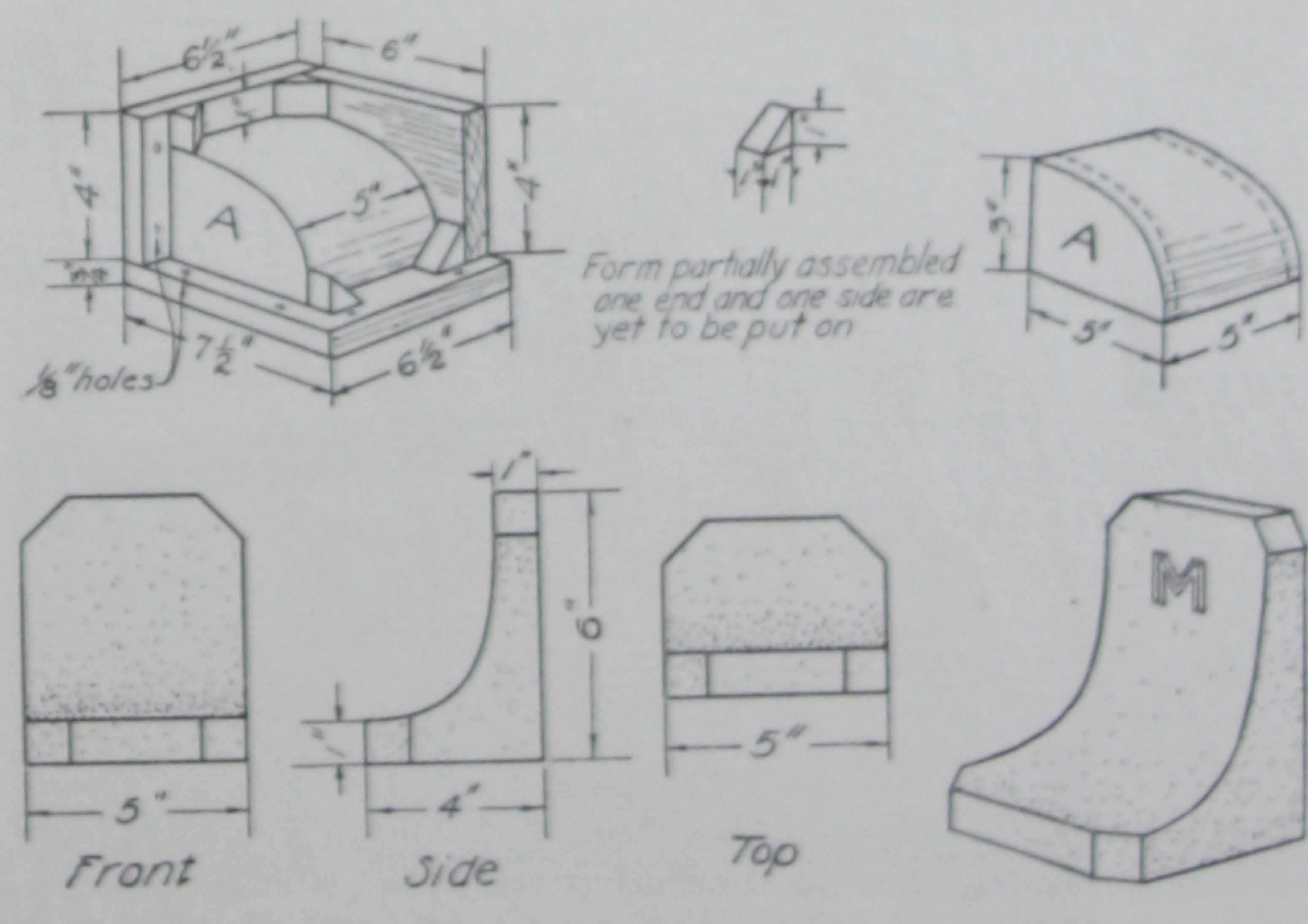
Book Ends

An attractive set of book ends adds much to the appearance of the desk or the library table. An almost unlimited number of designs is possible and, if desired, the book ends may be made in color by adding mineral pigments to the mortar or by using special aggregates such as crushed colored marble and granite.

Letters, rosettes, or swastikas, etc., may be cast on the exterior faces by cutting the desired forms from thin wood or fibre sheets and attaching to the form. It must be remembered that the form must be made reversed from that desired in the concrete.

The forms should be assembled with screws. Shellac all surfaces coming in contact with the mortar, and oil them just previous to using. Trowel exposed surfaces. Any bubbles or irregularities in the book ends may be patched after removal of forms. After the book ends have cured thoroughly, felt bases may be glued on.

Materials and Equipment—One pt. of cement; 3/5 pt. water; one qt. sand; oil; small mixing board; trowel; quart measure; sixteen 1¼-in. No. 10 flat head wood screws; one piece tin 5 in. by 8 in.; wood as required by



Construction of forms for concrete book ends is not difficult.

The design of book ends is limited only by the ingenuity of the student.

the drawings. (Approximate water-cement ratio—4½ gal. to sack, using moist sand.)

Hand Tamper

A concrete hand tamper is a practical tool to have around the home, particularly if any concrete work is to be done; it may be used to compact the base and subgrade for a sidewalk, a driveway or similar work.

The handle of the tamper should be held in the center of the form and about 1 in. above the pallet while the concrete is placed around it. Note how the handle is notched at the lower end and that nails are driven through it to prevent the handle from pulling out or turning. The top edges of the tamper may be beveled with a trowel.

Materials and Equipment—One qt. of cement; 1⅓ pt. water; 2 qt. sand; 3 qt. pebbles; oil; trowel; quart measure; wood pallet; 4 strips triangular mold; handle from discarded broom, hoe or rake; lumber as required by the drawing. (Approximate water-cement ratio—5 gal. per sack, using moist aggregates.)

A hand tamper is useful for many jobs around the home.

Pedestal

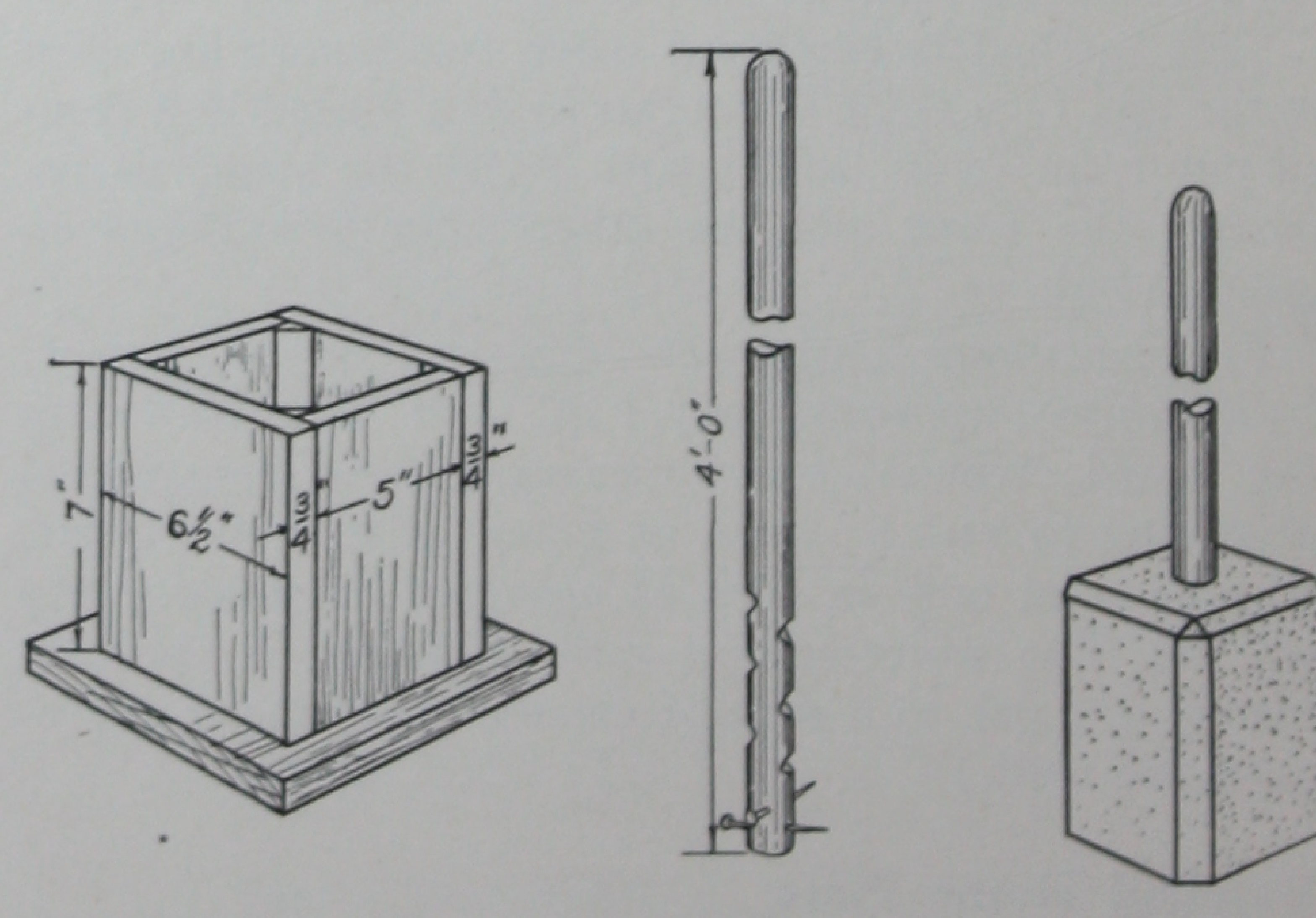
A concrete pedestal may be used for supporting garden and porch ornaments such as flower boxes, vases, sundials, bird baths and gazing globes. The design shown on page 57 is suggestive only, as many variations are possible. Suggestions for color or surface treatment are given in chapter VII.

The base, top and shaft are made separately and assembled by means of dowels after they have hardened. The base and top being identical, are cast in the same form. Forms should be carefully sanded, shellacked and oiled on surfaces coming in contact with the concrete. The forms should be fastened with screws to facilitate removing from the concrete and to permit re-use. Be sure to make provisions in the forms for making dowel holes in all three of the sections.

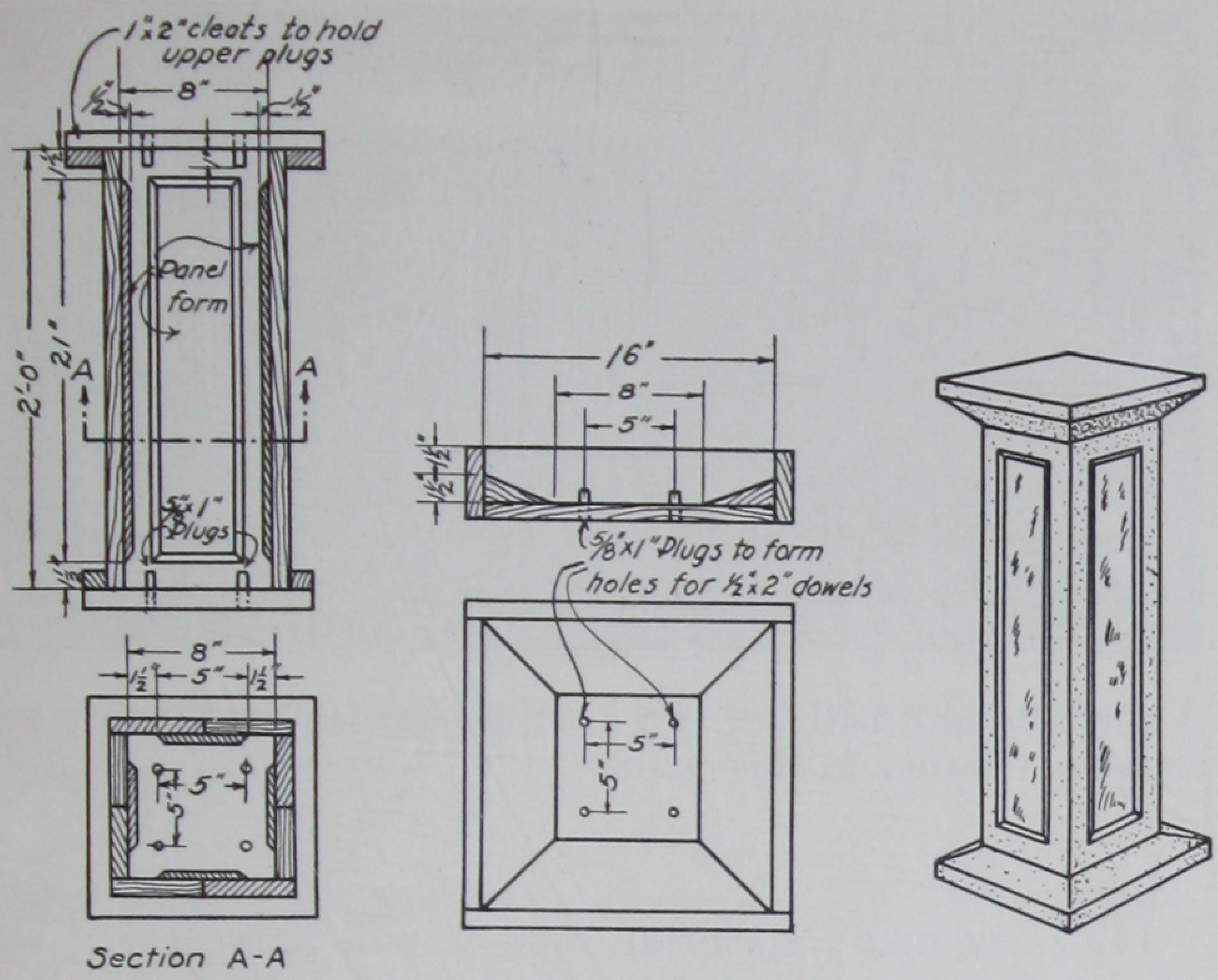
The pieces should harden at least 48 hours before assembling. Set the dowels in the holes provided with a medium wet mixture of cement and water. Spread a thin layer of the same mixture between the base and the shaft and also between the shaft and the top to bond the parts together. Airholes or other irregularities may be patched at this time.

Materials and Equipment—Two-thirds cu. ft. of cement; 3 gal. of water; one cu. ft. of sand; 1⅓ cu. ft. of pebbles; oil; mixing board; shovel; trowel; 8 round metal dowels, ½ in. by 2 in.; forms constructed as shown in drawings, page 57. (Approximate water-cement ratio—4½ gal. per sack, using moist sand.)

A partial list of other articles which can be made



Form for hand tamper. Note method of anchoring handle into concrete.



Forms for building concrete pedestal for sun dial or other garden ornaments.

either in the laboratory or as home projects, is given below:

- flower box
- lawn roller
- shoe scrape
- chimney cap
- garden bench
- lawn and garden pool
- bird bath
- water trough
- hot bed or cold frame
- refuse burner
- sun dial
- sidewalks
- flagstone walks
- driveways and approaches
- feeding floors for hogs
- paved barnyards
- barn floors and mangers
- basement floors
- steps and porch floors
- rat proofing buildings
- walls and footings
- garden and retaining walls
- machine foundations
- watering tanks
- milk cooling tanks
- septic tanks
- well curbs and platforms
- cisterns
- storage cellars
- manure pits
- implement sheds
- poultry houses
- hog houses
- ice houses
- milk houses
- dairy barns
- silos
- cribs and granaries

PROBLEMS

A list of problems is herewith presented, with the suggestion that the instructor supplement the laboratory and classroom work with regular problem assignments. The solution of problems affords a most effective means of bringing to the student an intelligent understanding of the proportioning of concrete mixtures, together with the practical experience of estimating quantities and costs.

1. How many sacks of cement will be required for a driveway using 8½ cu. yd. of concrete? How many cu. ft. of sand will be required? How many cu. ft. of pebbles will be required? How many gallons of water?

2. What will be the total volume in cu. yd. of concrete mixed in 23 one-sack batches, concrete to be used for heavy foundation work?

3. Find the volume of concrete required in a foundation of a rectangular building 31 ft. by 62 ft. outside dimensions, wall to extend from frost line to 12 in. above grade. Frost line is considered 3 ft. below grade. Wall averages 10 in. in thickness. Wall area of 18 sq. ft. to be deducted for openings.

4. Find the approximate amounts of sand, cement, pebbles and water required for the foundation mentioned in problem No. 3.

5. How many sq. ft. of sidewalk can be made per sack of cement, making the slabs 5 in. thick?

6. How many loads of cement will be required for the foundation mentioned in problem No. 3 if the wagons or trucks in which hauling is done can carry two tons over the roads which must be traversed in making this delivery?

7. A tank wagon holds 20 barrels of water. Each barrel holds 31½ gal. How many loads will be required to furnish mixing water for 108 cu. yd. of concrete if 5 gal. of water are required per sack of cement?

8. A circular water tank provided to supply steam traction engines is 18 ft. inside diameter and 20 ft. in height from footing to top of wall; maximum water depth is 15 ft. How much water will it hold in gallons and barrels?

9. In the above tank the first 3 ft. of wall is 8 in. thick, the remainder 6 in. If the floor is 8 in. thick, placed 4 ft. above bottom of footing, how much cement, sand, pebbles and water will be used to construct the job?

10. A concrete counterweight to weigh 15 tons is required for a bridge. A space 10 ft. square, any height, is available. If made to occupy the 10 by 10 space, how high will the weight be? Assume weight of concrete to be 145 lb. to the cu. ft.

A sun dial is an appropriate addition to the garden.

Concrete is widely used for outdoor play facilities. At the top is a concrete ping-pong table in a public park. Next below is a concrete shuffleboard court. At the bottom is a court for paddle tennis—a new game requiring much less space than ordinary tennis.

A concrete bird bath set in a concrete garden pool makes an attractive corner in this yard.

11. How many sacks of cement will be required to make the counterweight in problem No. 10? How many cu. yd. of sand and pebbles? How many gallons of water?

12. How many cu. ft. of 1-3 cement-sand mortar in 100 concrete sewer pipes; inside diameter 38 in., length 4 ft., thickness of wall 5 in.? What is the weight per pipe?

13. Compute cement, sand and pebbles required to build one mile of concrete road, width 20 ft., average thickness of slab 7 in.

14. What quantity of cement, sand, pebbles and water will be required to construct 100 fence posts 5 by 4 in. at the base, tapering on two sides to 3 by 4 in. at the top, made 7 ft. long?

15. A concrete products plant has gang fence post molds sufficient to make 200 posts of size given in problem 14. How many charges of a two-sack batch mixer will be required to fill the molds?

16. Find cost of materials required to build a retaining wall 20 ft. long, 4 ft. high and 2 ft. thick at base and 1 ft. thick at top. Use quotations from your market.

17. Assuming that ¼-in. reinforcing rods weigh 0.167 lb. per foot, what will be the total weight of rods required to reinforce 100 posts as described in problem No. 14, using four rods to the post?

18. Compute the amount of cement, sand, pebbles and water required to construct a set of steps if each step has 7-in. riser, 12-in. tread and is 4 ft. long. Assume distance from edge of front step to house wall is 5 ft.

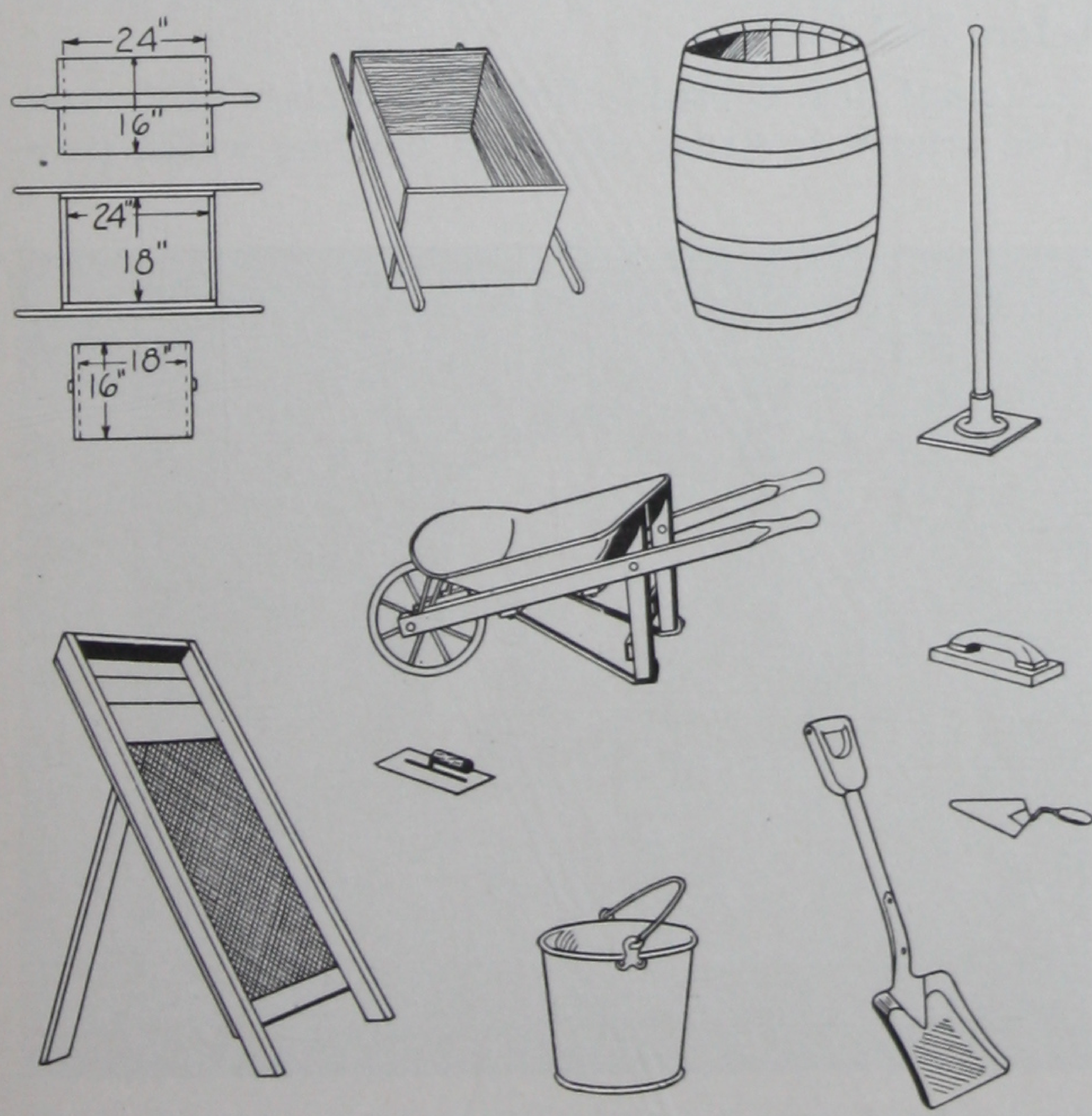
19. How many sacks of cement will be required to construct a concrete feeding floor 18 ft. square and 4 in. thick? How many gal. of water will be required?

Equipment

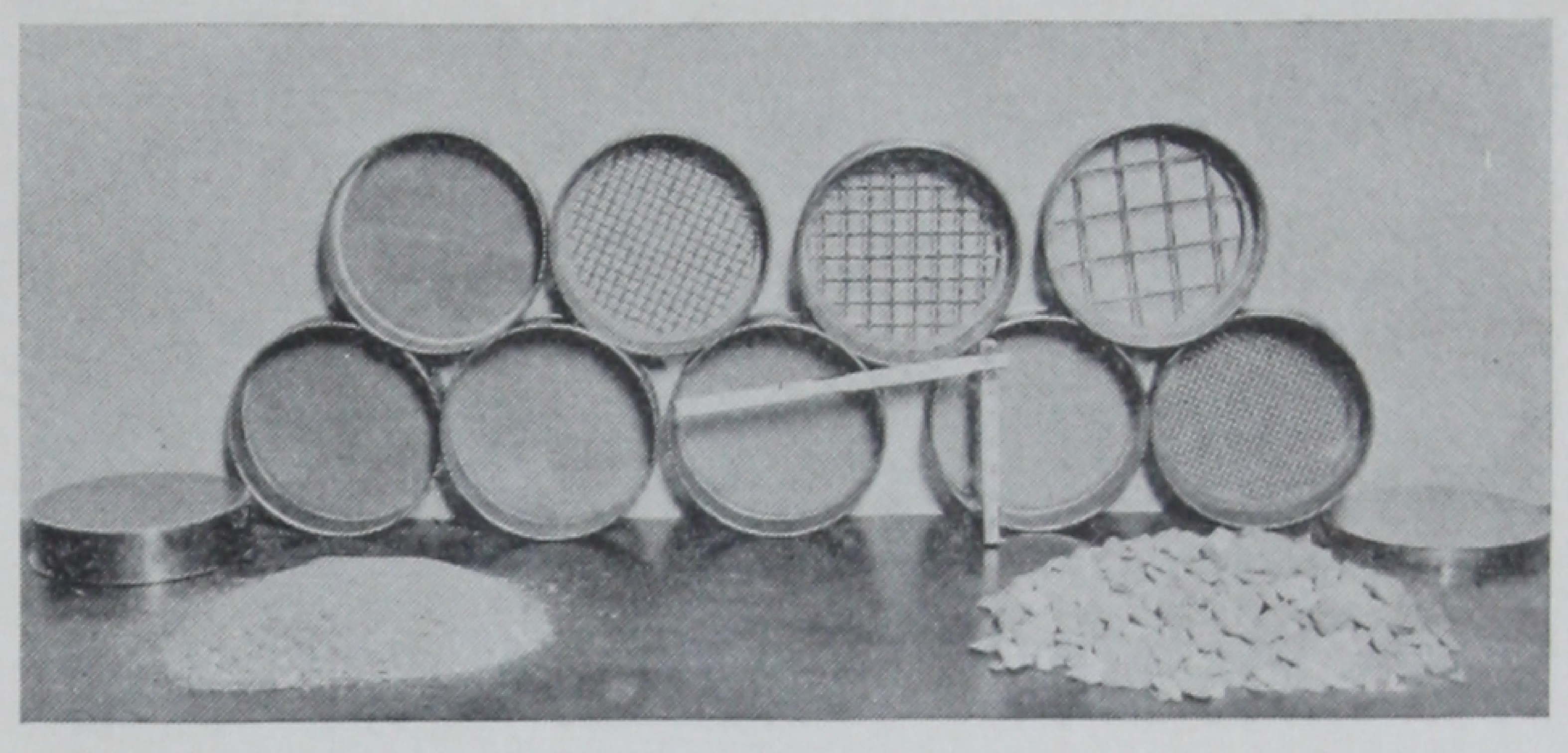
The equipment needed for a course in concrete may be roughly divided into that used for making the laboratory tests and field equipment necessary for concrete construction.

Laboratory Equipment

In so far as possible, the laboratory work has been planned to use equipment ordinarily found in a school's agricultural or physics laboratory. Some additions may easily be obtained or the skillful teacher can often modify the work slightly to use other equipment. Standard testing sieves have been so made that the openings in any screen are just half as large as those in the preceding larger size and twice as large as those in the succeeding smaller size. Some variations in the manufacturer's listing of this number of meshes in the smaller sizes may mean that one manufacturer has used a larger size wire in the screen. A customary designation is ¾-in., ⅜-in., 4, 8, 14, 28, 48, 100, 200. Soil testing sieves with different grading may be substituted if the results are modified accordingly.



Some typical equipment for concrete work in the home or school shop.



A standard set of laboratory sieves.

Other laboratory equipment needed follows:

Pans
Graduates (500 c.c.)
Scales
12 oz. prescription bottles
Quart fruit jars
Pieces of window glass (9 in. by 12 in.)
Slump cones.

Field Equipment

Most of the tools required in concrete work are simple and many of them can be home-made.

The principle ones are the following:

1. Screen
2. Mixing platform
3. Square pointed shovels
4. Measuring box
5. Water barrel
6. Pails
7. Hose
8. Tamper
9. Spading tool
10. Strike board
11. Wood float
12. Steel trowel
13. Edger
14. Groover
15. Wheelbarrow
16. Small wire brushes
17. Straight edge
18. Measures (gallon and quart)

A *sand screen* should be 2 ft. 6 in. or 3 ft. wide, and 6 ft. long. The frame may be made of 1½ or 2-in. lumber, 4 to 6 in. wide. Legs should be so attached to the sides that the screen can be set at the desired angle while throwing material upon it to separate the sand from the pebbles. This angle should be about 45 degrees. A piece of wire cloth or fabric having 3 meshes to the linear inch should be nailed to the frame. Material to be screened is thrown with a shovel against the upper portion of the screen and, in rolling down, the coarse aggregate is separated from the fine aggregate.

Where possible, concrete should be mixed by machine. Work can be done more quickly, and thorough mixing is assured.

For hand mixing, a watertight *mixing platform* at least 7 ft. wide by 12 ft. long should be provided. A platform of this size is large enough to permit two men using shovels to work upon it at one time.

It may be made by using a piece of sheet steel about ⅛ in. thick with 2 by 4's set on edge and properly fastened to three of the form edges or sides of the steel; or the platform can be made entirely of wood. In this case the floor of the platform should be of not less than 1½-in. lumber, 4 to 6 in. wide, tongued and grooved, and surfaced. If tongued and grooved lumber is not obtainable, the edges of the boards should be planed or jointed so that they can be nailed closely together on three 4 by 4-in. stringers, placed 2 ft. or more apart, to make a firm, unyielding platform. Two by four strips should be nailed to three sides so that materials will not be shoveled off the board in mixing.

The *measuring box* is necessary to measure exact quantities of sand and pebbles or broken stone. Such a box is a bottomless frame made of 1 or 1½-in. material and should have a capacity of not less than 1 cu. ft. If larger, it should be of 2 or 3-cu. ft. capacity and should be marked on the inside to show levels at which volume will equal 1 cu. ft., 2 cu. ft., etc. Handles are placed on the side of the box to make lifting easy after the material required has been measured.

DIMENSIONS FOR BOTTOMLESS MEASURING BOXES

Capacity In Cu. Ft.	Inside Measurements in Inches		
	Length	Width	Height
1	12	12	12
1½	15	15	11½
2	18	18	10⅝

Ordinary square pointed *shovels* are used for mixing concrete.

For transferring concrete from the mixer or mixing platform to the place of final use, a *wheelbarrow* may be needed. One with a sheet iron body should be used having the front of the body higher than the back to prevent loss of concrete when the barrow handles are raised in position for wheeling.

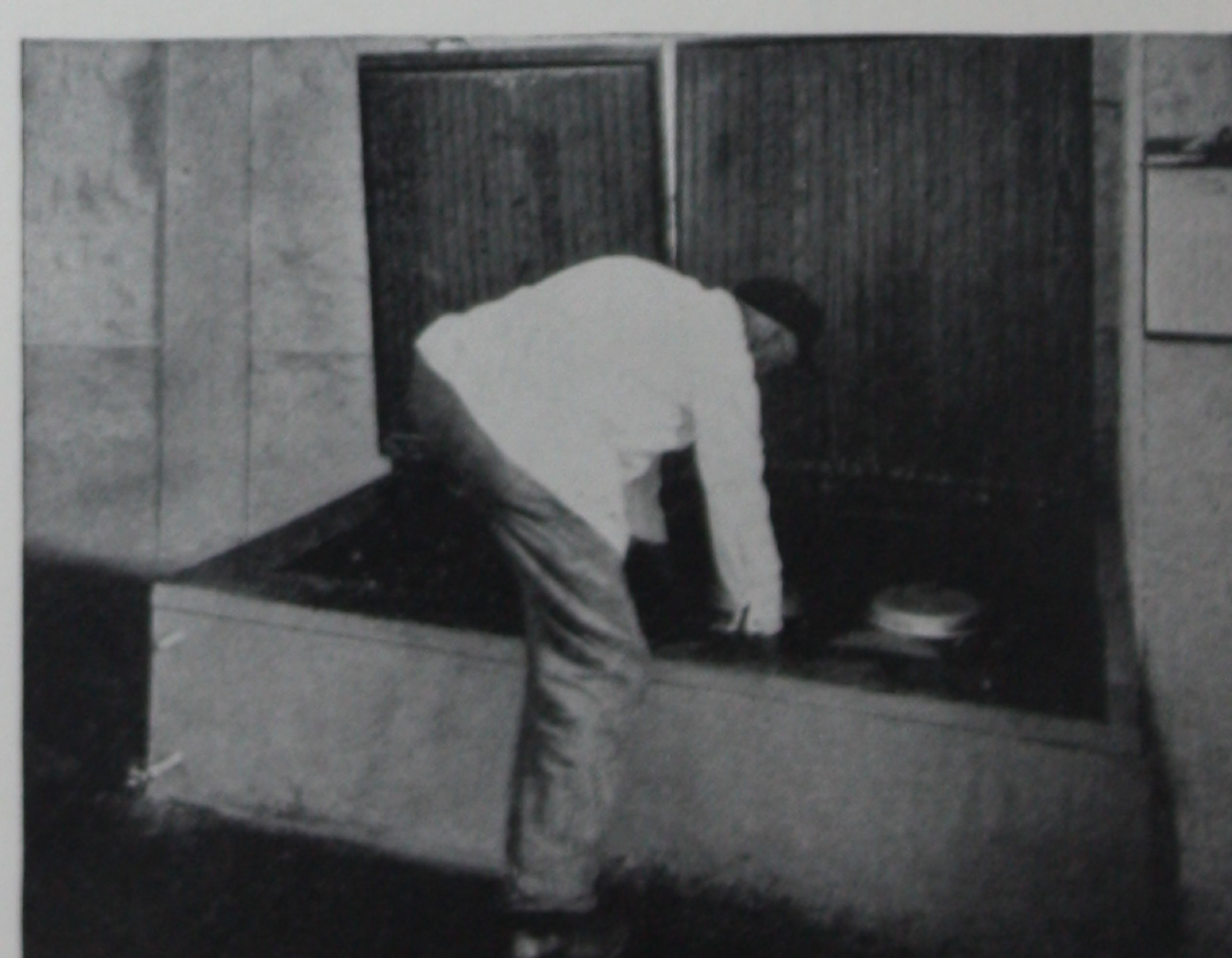
When placing concrete in forms, it must be spaded and tamped. A *tamper* may be made by boring a 1½-in. hole in the end of an 8 by 8 by 12-in. piece of timber and inserting a handle about 4 ft. long. A metal tamper may also be used, or one can be made of concrete.

A *spading tool* of some kind is necessary to settle the material in the forms properly and also to secure a surface finish free from pebble pockets. Such a spading tool may be made by flattening an ordinary garden spade or by straightening out an old garden hoe. Both tools are used by working them up and down in the concrete close to the form faces so as to force back coarse particles and bring sand-cement mortar to the form face.

Sometimes a chisel-edged board 4 to 6 in. wide may be used for spading concrete, the upper end being shaped to form a convenient handle. When reinforcing metal is placed in the concrete, smaller spading tools will be needed to work in the smaller spaces. Pointed sticks, steel rods, or narrow chisel-edged pieces of wood are used for this purpose.

A *strikeboard* is merely a piece of 1½ or 2-in. lumber, 4 in. or more wide, and long enough to rest across the top of the form, as in sidewalk construction, so that the top of the concrete can be approximately leveled before final finish.

A *wood float* is used to finish the surface of the concrete after it is struck off, as in building walks, pave-



An insulated concrete milk cooling tank enables the dairy farmer to cool milk quickly and keep it sweet for a longer period.

A concrete feeding floor will soon pay for itself in feed saved.

ments and floors. This is a simple tool and can be made by anyone.

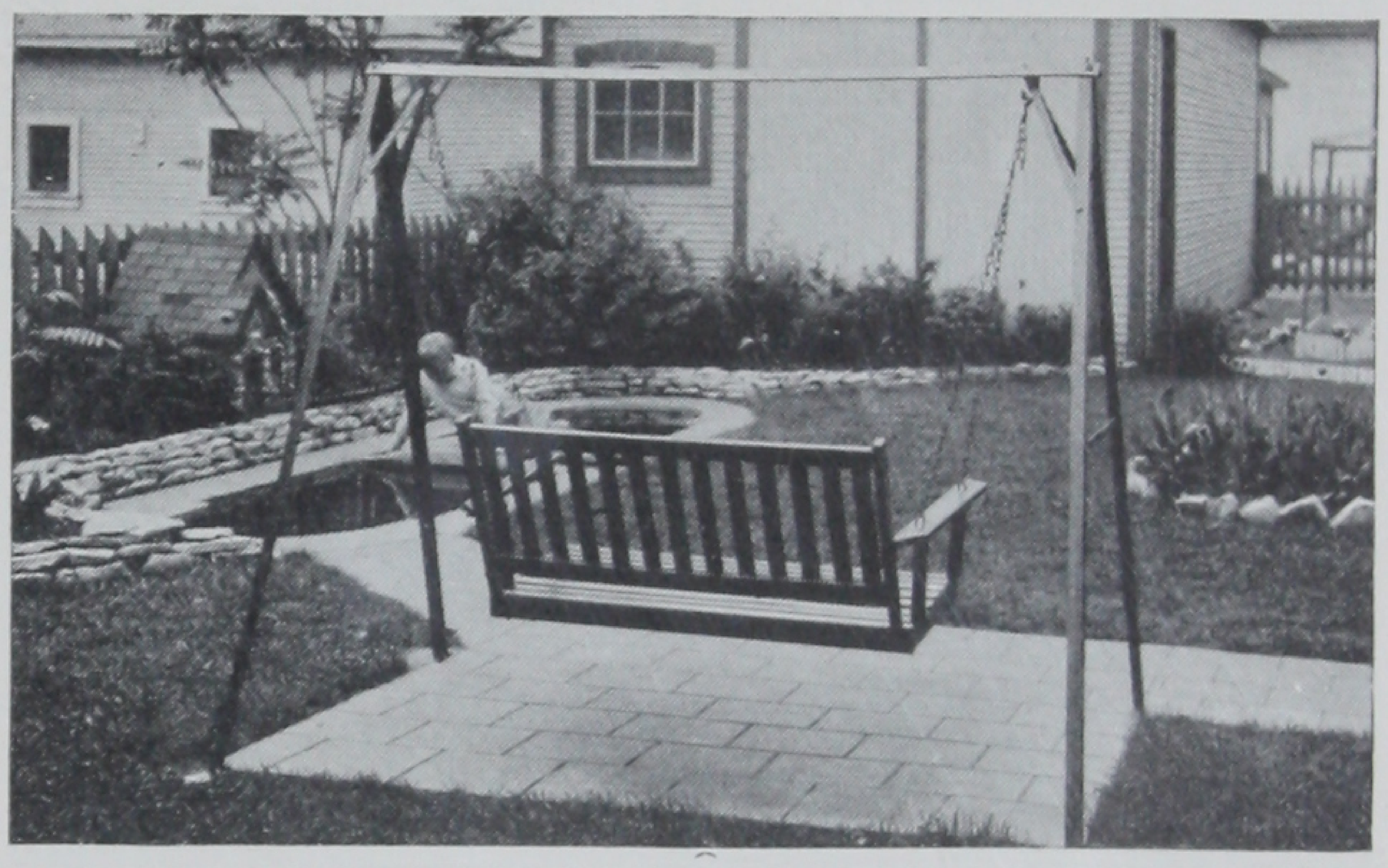
A *steel hand float or trowel* may sometimes be required where a smoother surface is desired than can be obtained with the wood float.

For finishing joints between slabs in walks, floors, and similar concrete work, a tool known as a *groover* is used, while for finishing the edges of the slabs the tool used is known as the *edger*.

A *water barrel and pails* are necessary for adding the required amount of water to the correctly measured materials.

Most of the batch *mixers* in use have revolving drums with fixed blades inside, though a few have fixed drums with revolving blades or paddles. The latter type is commonly used in block manufacture where very dry mixes are employed. The drums may be shaped like cylinders, double cones or cubes. Several manufacturers of concrete mixers make machines that are relatively cheap and at the same time very efficient.

The speed of the drum is important. If it rotates too fast, the materials will tend to be held next to the rim, while if the speed is too slow, thorough mixing will not be accomplished in the usual time. A peripheral speed of about 200 ft. per minute is satisfactory.



Concrete yard improvements make pleasanter living out-of-doors.

Bibliography

An attractive concrete floor marked to resemble tiling.

In this short manuscript, it is possible to treat the various phases of concrete construction very briefly at best. Every school shop should have accessible a library of books and bulletins covering the many phases of this work.

Usually, single copies of U. S. and college bulletins may be obtained for the asking.

A short list of books and bulletins appears below.

AMERICAN SOCIETY FOR TESTING MATERIALS.
Standard Specifications and Tests for Portland Cement. American Society for Testing Materials. 36 p. illus.

BETTS, M. C. and MILLER, T. A. H.
Small Concrete Construction on the Farm. U. S. Dept. Agr. Farmers' Bul. 1480. 38 p. illus. 1926.

DAVIDSON, J. B.
Concrete Fence Posts. Ia. Agr. Exp. Sta. Bul. 219. 32 p. illus. 1924.

DAVIDSON, J. B. and GIESE, HENRY.
The L-Block. A Type of Concrete Block Adapted to the Economical Construction of Farm Buildings. Ia. Agr. Exp. Sta. Bul. 249. 24 p. illus. 1928.

DAVISON, RALPH C.
Concrete Pottery and Garden Furniture. Munn & Co., New York. 196 p. illus. 1917.

MILLER, T. A. H.
Plain Concrete for Farm Use. U. S. Dept. Agr. Farmers' Bul. 127A. 27 p. illus. 1922.

SEATON, R. A.
Concrete Construction for Rural Communities. 234 p. illus.

Among the numerous publications of the Portland Cement Association will be found many booklets and pamphlets having a direct bearing upon various types of concrete construction. The following list is fairly representative. Copies may be obtained upon request.

Air Terminals.
Concrete Alleys.
Concrete Ashlar Walls.
Concrete Facts for Concrete Contractors.
Concrete Floor Finishes (industrial and commercial).
Concrete Floors for Residences.
Concrete Improvements Around the Home.
Concrete Industrial Driveways.
Concrete in Parks and Playgrounds.
Concrete Lily Pools.
Concrete Masonry Construction.
Concrete Septic Tanks.
Concrete Sidewalks.
Concrete Silos—Monolithic and Block.
Concrete Stave Silos.
Concrete Swimming Pools.
Concrete Tanks, Troughs and Cisterns.
Concreting in Cold Weather.
Dairy Barn Floors and How to Build Them.
Design and Control of Concrete Mixtures.
Facts About Concrete Masonry.
Foundation Walls and Basements of Concrete.
Home Garage of Concrete Masonry.
If Your Car Had Wings.
Low-Cost, Fireproof Concrete Homes.
Mineral Colors and Special Facing Aggregates.
Modern Poultry Houses.
Pavements for Modern Traffic.
Permanent Farm Construction.
Permanent Farm Repairs.
Permanent Improvements for Homes, Schools, Parks, Playgrounds and Industrial Plants.
Plans for Concrete Farm Buildings.
Plasterer's Manual.
Portland Cement Stucco in Color.
Precast Concrete Joists.
Salvaging Old Pavements With Concrete.
Sanitary Milk Houses.
Vibration—a Better Method of Placing Concrete.

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